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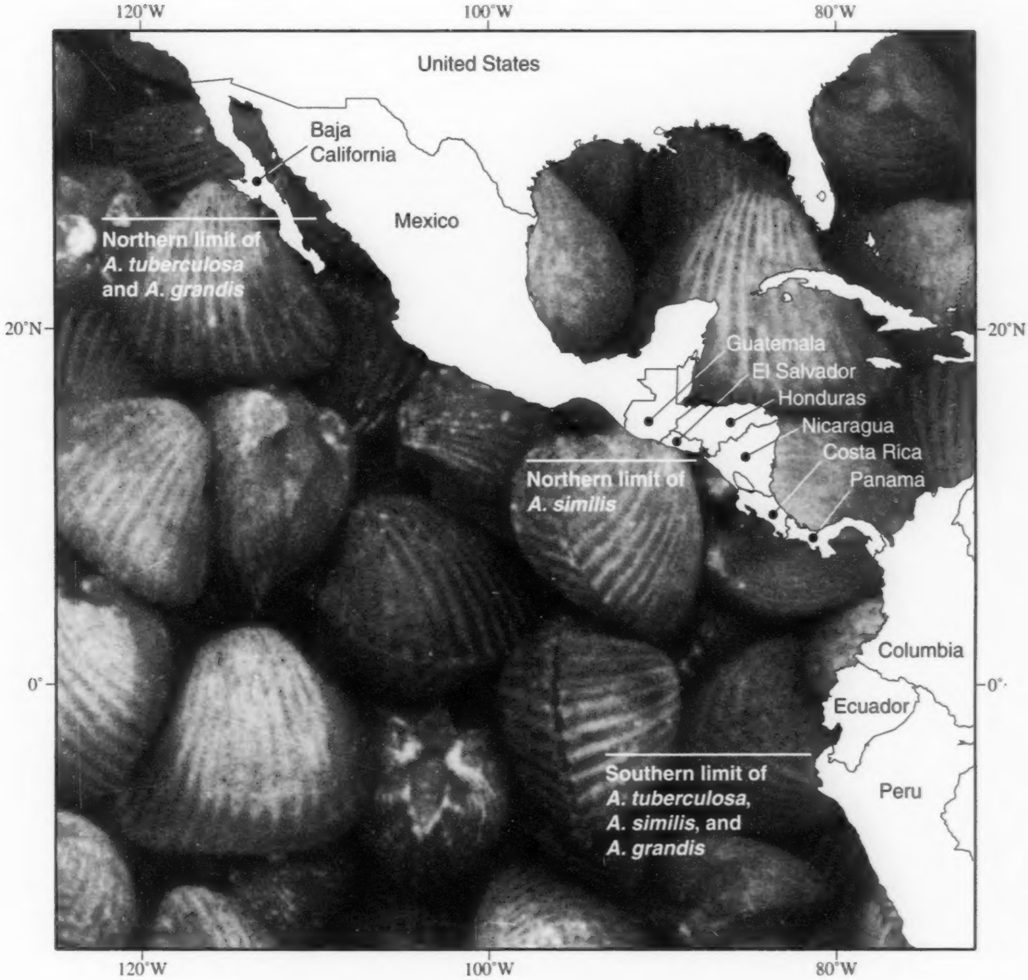
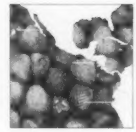


Mangrove Cockle Fisheries

Marine Fisheries REVIEW

W. L. Hobart, Editor
J. A. Strader, Managing Editor

On the cover:
The northern and southern limits
of *Anadara tuberculosa*, *A. similis*,
and *A. grandis* off the Pacific Coast
of North, Central, and South America
superimposed over a basket of *A. grandis*.



Articles *63(1), 2001*

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The Fisheries for Mangrove Cockles, *Anadara* spp., from Mexico to Peru, With Descriptions of Their Habitats and Biology, the Fishermen's Lives, and the Effects of Shrimp Farming

CLYDE L. MacKENZIE, Jr.

Introduction

Mangrove cockles (also called ark shells) of the genus *Anadara* are harvested for food by large numbers of artisanal fishermen in the Pacific coast lagoons of 10 countries from Mexico through Central America to Peru. The extent of their range is about 6,350 km (4,000 miles) (Fig. 1). The cockles are by far the most important commercial mollusks along this coastline, which encompasses a biogeographic zone that Briggs (1974) defined as the Tropical East Pacific Region. Cockles occur among or near mangrove trees, mainly the red mangrove, *Rhizophora mangle*.

Three species are harvested, all by hand. In order of abundance, they are *A. tuberculosa, A. similis,* and *A. grandis.* This fishery heretofore has not been described in the international literature except in Nicaragua (MacKenzie and Lopez, 1997) and Colombia (Squires et al., 1975). Studies have been made of the cockles' reproduction in Costa Rica (Cruz, 1984a, b, 1987a, b; Ampie and Cruz, 1989), population densities in Mexico (Baquiero, 1980), and associated macrofauna in Colombia (Squires et al., 1975; Blanco and Cantera, 1999).

This paper reviews the literature on mangrove cockle fisheries in Nicaragua and Colombia and the ecology and biology of the cockles, and it presents the results of my recent surveys of the cockle fisheries and my biological notes in the remaining cockle-producing countries: Mexico, Guatemala, El Salvador, Honduras, Costa Rica, Panama, Ecuador, and

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ABSTRACT—This paper provides the first description of the mangrove cockle, Anadara *spp., fisheries throughout their Latin American range along the Pacific coast from Mexico to Peru. Two species,* A. tuberculosa *and* A. grandis, *are found over the entire range, while* A. similis *occurs from El Salvador to Peru.* Anadara tuberculosa *is by far the most abundant, while* A. grandis *has declined in abundance during recent decades.* Anadara tuberculosa *and* A. similis *occur in level mud sediments in mangrove swamps, comprised mostly of* Rhizophora mangle, *which line the mainlands and islands of lagoons, whereas* A. grandis *inhabits intertidal mud flats along the edges of the same mangrove swamps. All harvested cockles are sexually mature. Gametogenesis of the three species occurs year round, and juvenile cockles grow rapidly. Cockle densities at sizes at least 16–42 mm long ranged from 7 to 24/m*^{2} *in Mexico. Macrofaunal associates of cockles include crustaceans, gastropods, and finfishes. The mangrove swamps are in nearly pristine condition in every country except Honduras, Ecuador, and Peru, where shrimp farms constructed in the 1980's and 1990's have destroyed some mangrove zones. In addition, Hurricane Mitch destroyed some Honduran mangrove swamps in 1998.*

About 15,000 fishermen, including men, women, and children, harvest the cockles. Ecuador has the largest tabulated number of fishermen, 5,055, while Peru has the fewest, 75. Colombia has a large number, perhaps exceeding that in Ecuador, but a detailed census of them has never been made. The fishermen are poor and live a meager existence; they do not earn sufficient money to purchase adequate food to allow their full health and growth potential. They travel almost daily from their villages to the harvesting areas in wooden canoes and fiberglass boats at low tide when they can walk into the mangrove swamps to harvest cockles for about 4 h. Harvest rates, which vary among countries owing to differences in cockle abundances, range from about 50 cockles/fisherman/day in El Salvador and Honduras to 500–1,000/fisherman/day in Mexico. The fishermen return to their villages and sell the cockles to dealers, who sell them mainly whole to market outlets within their countries, but there is some exporting to adjacent countries. An important food in most countries, the cockles are eaten in seviche, raw on the half-shell, and cooked with rice.

The cockles are under heavy harvesting pressure, except in Mexico, but stocks are not yet being depleted because they are harvested at sizes which have already spawned. Also some spawning stocks lie within dense mangrove stands which the fishermen cannot reach. Consumers fortunately desire the largest cockles, spurning the smallest.

Cockles are important to the people, and efforts to reduce the harvests to prevent overfishing would lead to severe economic suffering in the fishing communities. Programs to conserve and improve cockle habitats may be the most judicious actions to take. Preserving the mangrove swamps intact, increasing their sizes where possible, and controlling cockle predators would lead to an increase in cockle abundance and harvests. Fishes that prey on juvenile cockles might be seined along the edges of swamps before the tide rises and they swim into the swamps to feed. Transplanting mangrove seedlings to suitable areas might increase the size of those habitats. The numbers of fishermen may increase in the future, because most adults now have several children. If new fishermen are tempted to harvest small, immature cockles and stocks are not increased, minimum size rules for harvestable cockles could be implemented and enforced to ensure adequate spawning.

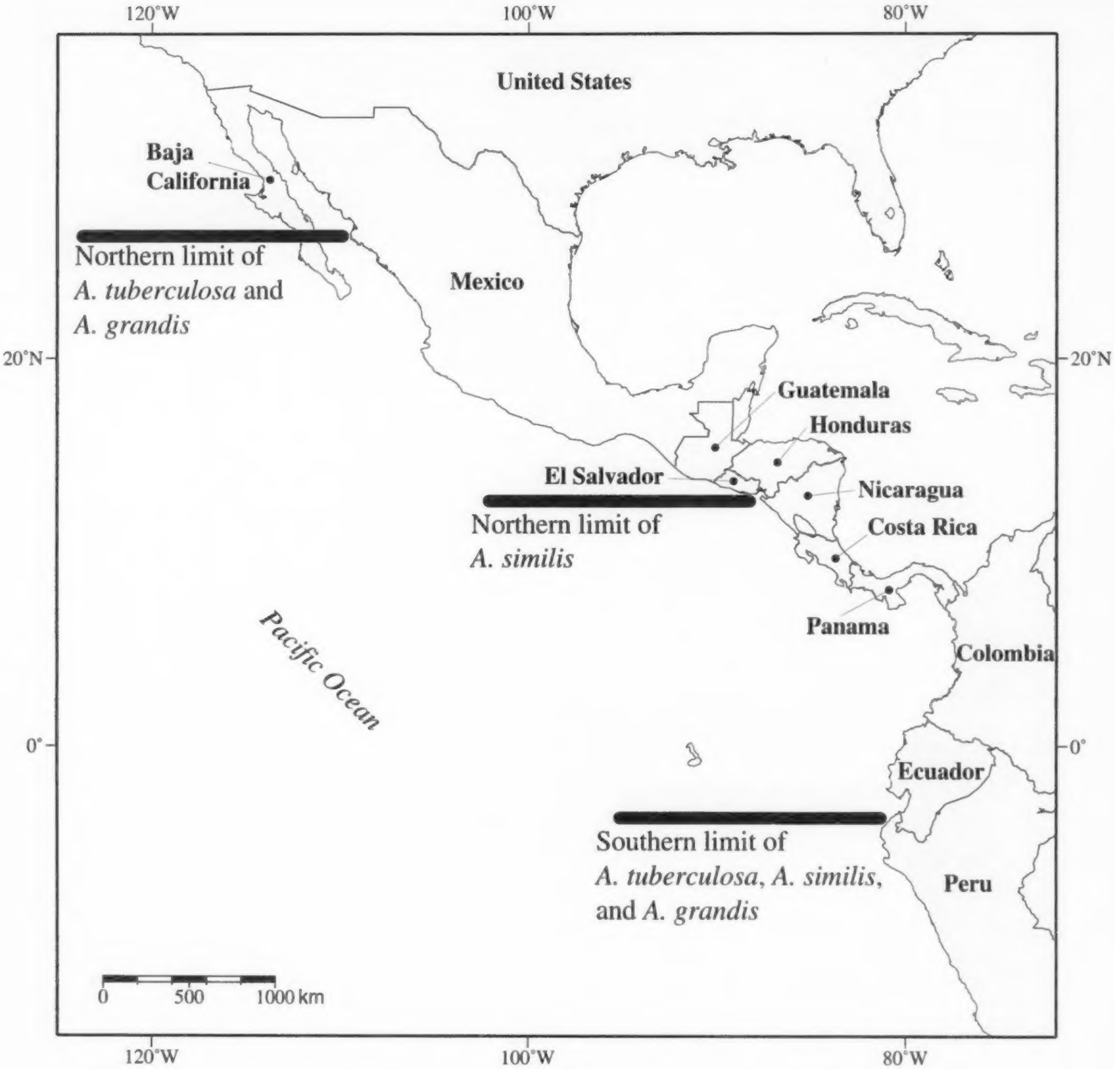

Figure 1.—Ranges of the cockles *Anadara tuberculosa*, *Anadara similis*, and *Anadara grandis*, and the countries in which they are harvested; the cockles are not harvested in the United States.

Peru. Included are the following sections: 1) the ranges, morphology, habitat, and biology of the cockles, 2) the fishermen's lives in the villages, 3) overall conduct of the fisheries, 4) data and observations in individual countries, and 5) effects of shrimp farming in Ecuador on the mangrove habitat and fishery. Suggestions follow for research and management.

The fishermen's lives are little known and largely ignored by government officials and other citizens in the Latin American countries themselves. A lengthy description of them is included so government managers can accurately predict the consequences to the fishing communities of any proposed changes in policies regarding the cockle and the mangrove resources. Such descriptions have rarely been documented in historical or current accounts of the world's fisheries (Hobart[1]). This description may also provide useful information for humanitarian groups concerned with the welfare of Latin American people.

Methods

In 1998, 1999, 2000, and 2001, I made 10 trips to Latin American coun-

[1] Hobart, Willis L., Chief, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115. Personal commun.

tries to visit all the principal mangrove cockle harvesting regions, spending 1–4 weeks in each country. I traveled with a local guide and interpreter by automobile or pickup truck from village to village interviewing fishermen, dealers, and local residents to obtain a census of the number of fishermen, and to learn about the equipment and methods used, working hours, sizes of harvests, prices, marketing, and local ways the cockles are prepared as food. I also visited some mangrove swamps to observe fishermen harvesting cockles and some markets to observe selling practices. In addition, I photographed typical scenes. In April, June, and September of 2000, and in January of 2001, while visiting villages in Honduras and El Salvador, I also asked fishermen about the condition of their lives. According to the villagers in every country, this was the first such survey made of the cockle fisheries or what their lives are like. For this paper, the monetary units used in each country have been converted to U.S. dollars. The Appendix provides additional details regarding my survey methods.

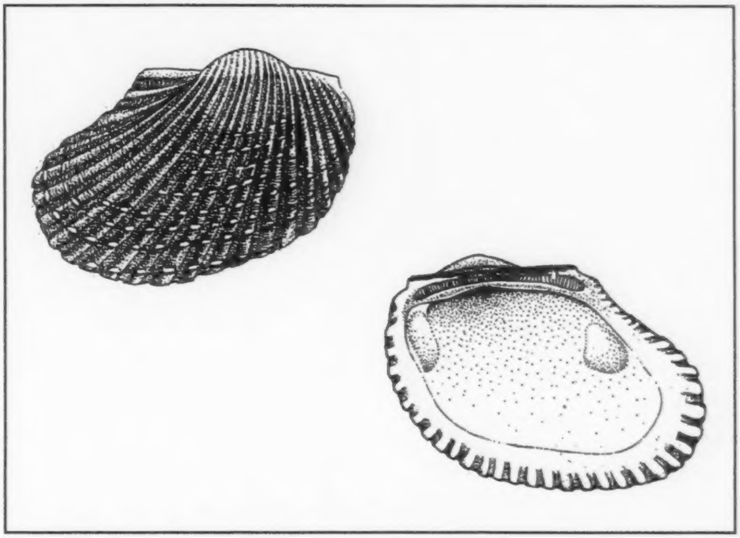

Figure 2.—Exterior and interior views of the valves of *Anadara tuberculosa* (from Mora Sanchez, 1990).

Figure 3.—Part of a pile of *Anadara tuberculosa*. The largest cockles are about 60 mm long.

Cockle Ranges and Descriptions

Anadara tuberculosa

The geographic range of *A. tuberculosa* is from Laguna Ballena, Baja California Sur, Mexico, to Bahia de Tumbes, Peru (Mora Sanchez, 1990; Cruz and Jimenez, 1994). This species has two valves of equal shape, and they are obliquely oval (Fig. 2, 3). Each valve has 34–37 radial ribs and a dark brown periostracum with bristles between the ribs. The dorsal margin of the valves is angular. No sexual dimorphism is present in the length-weight ratio. In Costa Rica, the percentage of dry meat in *A. tuberculosa* in its length range of 42–47.5 mm is 20%; within its length range of 54–59.5 mm (when the shell was thicker), it is 16%; and for all sizes it averages 18% (Cruz and Palacious, 1983). Squires et al. (1975) said wet meat weights of *A. tuberculosa* in Colombia are 36% of total weight at small sizes (36–42 mm) and slightly more than 15% at large sizes. The blood of *A. tuberculosa* is black.

I measured the lengths of harvested *A. tuberculosa* in 7 countries (Fig. 4). Harvesting effort for cockles varies widely among countries and is described below. Where harvesting is lightest, as in Mexico, the cockles had a longer chance to grow and were as large as 75 mm. Where harvesting is heaviest, as in Guatemala, El Salvador, and Peru, the cockles were the smallest because they had the least time to grow, and nearly all were under 55 mm. The mid-sized cockles were in Honduras, Panama, and Ecuador. All harvested cockles in every country had attained a size at which they were sexually mature.

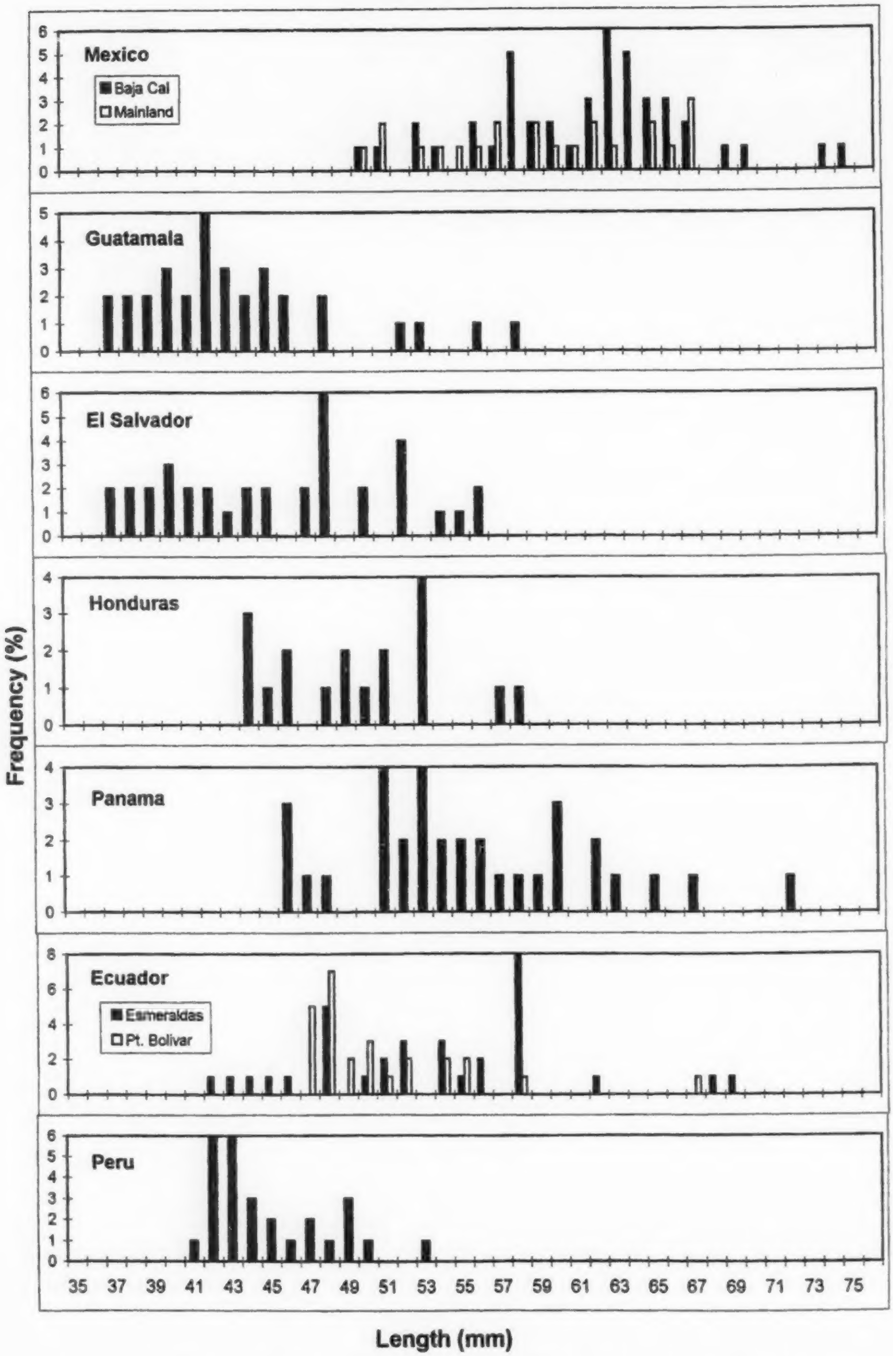

Figure 4.—Length-frequencies of commercially-harvested *Anadara tuberculosa* in selected countries.

Anadara similis

A. similis ranges from the Golfo de Fonseca, El Salvador, to Bahia de Tumbes, Peru (Cruz and Jimenez, 1994). *A. similis* is similar in size and appearance to *A. tuberculosa*, except that each valve has 40–44 ribs, and its periostracum is without bristles. The dorsal margin is rounder and less angular, and its shell is thinner and more fragile (Fig. 5). The blood of *A. similis* is red.

Anadara grandis

A. grandis ranges from Bahia Magdalena, Baja California, Mexico, to Bahia de Tumbes, Peru (Mora Sanchez, 1990). It grows to a much larger size than the other two cockles. Its valves are almost square, and their length almost equals their height. The valves are convex with high umbos, and they have 26 ribs separated by deep interspaces (Fig. 6). The shell has a dark periostracum, and the blood of *A. grandis* is red.

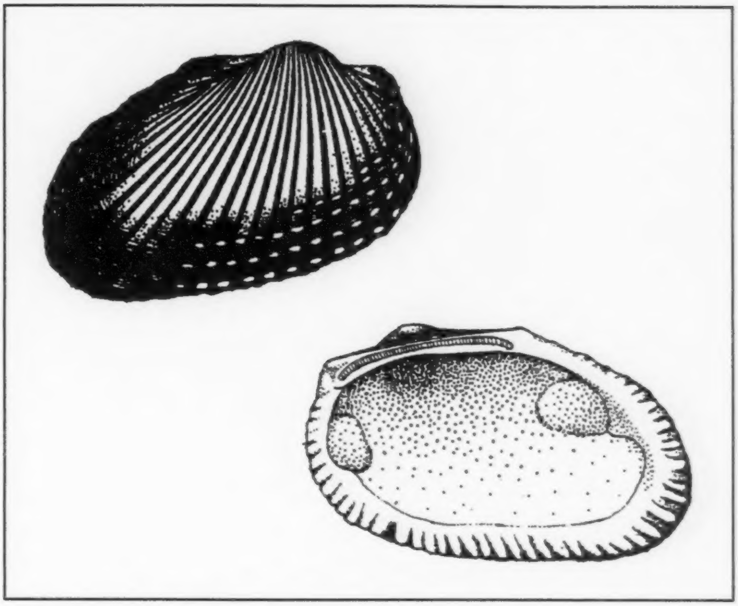

Figure 5.—Exterior and interior views of *Anadara similis* valves (from Mora Sanchez, 1990).

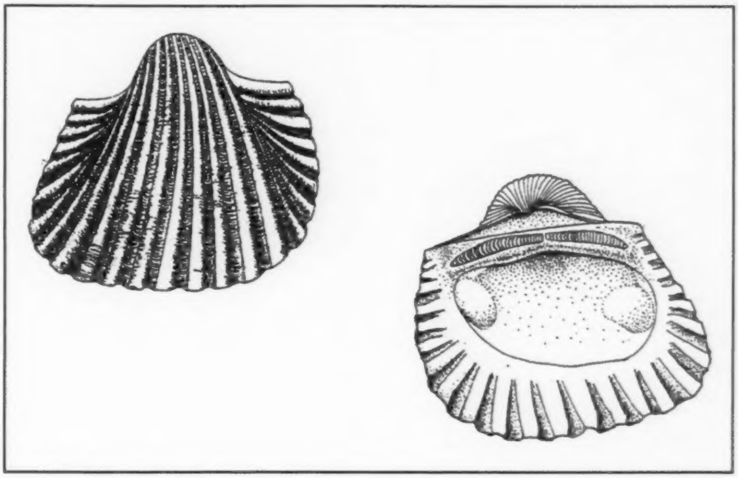

Figure 6.—Exterior and interior views of *Anadara grandis* valves (from Mora Sanchez, 1990).

Cockle Habitats

A. tuberculosa and *A. similis* inhabit level mud sediments in mangrove swamps which occur along the mainlands and islands of lagoons. *A. tuberculosa* occurs among the aerial prop roots and under the canopies of the mangrove trees; most are about 15 cm deep in the mud (from the tips of one's fingers to the wrist). *A. similis* occurs in open areas away from the prop roots but also under the tree canopies, and most are about 45 cm deep (from the tips of one's fingers to the elbow). The distribution of the two species overlaps a little. In addition, sparse quantities of *A. tuberculosa* and *A. similis* occur in intertidal mud flats between the mangrove trees and the low tide line (Rosero[2]). In the northernmost countries at least, *A. tuberculosa* is found deeper in the mud and fewer can be harvested during the winter. It was not determined whether the cockles are nearer the mud surface during high tides. The location of *A. tuberculosa* is shown by a round 2–3 mm hole on the mud surface, but the fishermen just feel around the prop roots to find them. *A. similis* can be found by spotting a 2 × 8 mm oval hole without fecal material around it on the mud surface. A burrowing crab makes a similar hole with feces on the surface.

The swamps become flooded with estuarine water during mid and high tides, and their mud substrates are covered by 1 m or more of water. The water drains off during ebbing tides, and their substrates are left bare for about 4 h during

[2] Rosero, Javier, Chief of Fisheries, Technology Area, Instituto Nacional de Pesca, Letamendi 102 y La Ria, Guayaquil, Ecuador. Personal commun., November, 1999.

Figure 7.—The edges of a Honduran intertidal mud flat and mangrove-cockle swamp at low tide; many flats are broader than this. The fisherman is seeking *Anadara tuberculosa* and *A. similis*.

low tides (Fig. 7). The widths of the zones (from the edge of the mangrove canopy and prop roots near the water to high ground inland) inhabited by *A. tuberculosa* and *A. similis* vary from about 7 to 200 m but are mostly 50 to100 m wide. Squires et al. (1975) said the overall widths of the mangrove swamps in Colombia average 150 m with about 100 m of this occupied by cockles.

A. tuberculosa is most abundant in the mud zones of the red mangroves, *R. mangle*, while much lower densities occur in such zones of the black mangroves, *Avicenia germinans*, where sediments are more compact and have more woody fiber. This species is never found in sandy or shelly bottoms even in the presence of red mangroves (Baquiero, 1980). Elba Mora de Banos[3], with the Instituto Nacional de Pesca in Guayaquil, Ecuador, believes the *A. tuberculosa* likely are abundant in the mangrove swamps because the prop roots offer them cover from predators, while noting that the *A. similis*, with less root protection, are much deeper in the mud. She believes the two species may set in the flats and subtidal areas beyond the extent of the flats bordering the mangroves, but that most are probably eaten by predators.

A. grandis inhabits intertidal flats and some subtidal areas beyond the edges of mangrove swamps and is much less abundant than the other two species. Harvested over much of its range, its abundance has declined in recent decades.

The associated macrofauna of *A. tuberculosa* and *A. similis* in Colombian mangrove swamps include the tree-climbing crab, *Goniopsis gaudichaudi;* hermit crabs of several species; various shrimp species; small fishes (Squires et al., 1975); and at least five gastropod species (Blanco and Cantera, 1999). Cockle fishermen (personal commun.) related they found some dead cockles with bore holes made by gastropods. The associates also include alphaeid shrimps that make a loud snapping or popping noise when the tide is low and has left the mangrove substrates bare (Squires et al., 1975). The noise is made in mangrove swamps from Mexico through Peru at least once or twice a minute. Fishes swim into the swamps during high tides seeking food. One fish group, tetradonts, eats small cockles, at least in Mexico (Luis[4]) and Ecuador (Mora de Banos[3]), and perhaps Honduras (personal commun., several fishermen).

The mangrove swamps are in a nearly pristine condition in all countries except Honduras, Ecuador, and Peru. In Honduras, the construction of shrimp farms and Hurricane Mitch (November 1998) have destroyed large areas of several mangrove swamps, some harboring cockles, but most are in good condition. In Ecuador and Peru, shrimp farms have removed even larger sections of mangrove swamps (as later discussed). The governments of Honduras (Anonymous, 1999a,b) and Ecuador (Altamirano et al., 1998) have declared that some mangrove areas will be protected from human destruction.

Cockle Biology

A critical aspect in the management of the mangrove cockle fishery is the shell length at which the cockles become mature and spawn. Researchers in Costa Rica have determined these lengths for *A. tuberculosa* and *A. grandis*, but as yet no one has reported on it for *A. similis*. In *A. tuberculosa*, maturity and spawning begin at shell lengths of 23–26 mm (Ampie and Cruz, 1989), while in *A. grandis* they begin at lengths of 21–24 mm (Cruz, 1987b).

In Costa Rica, ripening and fully ripe *A. tuberculosa* are present throughout the year; also, its sex ratio is 1:1, and there is no sex reversal. Its period of greatest spawning activity is during May–September, with 70% of the cockles spent in May and 50% spent in September (Cruz, 1984a). In *A. similis* (Cruz, 1984b) and *A. grandis* (Cruz, 1987a; Fournier and de la Cruz, 1987) also, gametogenesis occurs year round, their sex ratios are 1:1, and there is no sex reversal (Fig. 8). In *A. similis*, in 1981 and 1982, specimens were of maximum ripeness in December 1981 and in February and December 1982 (Cruz, 1984b). In *A. grandis*, spawning individuals were most prevalent in November and least prevalent in April, and mature individuals appeared most commonly between July and September, the months preceding the November peak

[3] Mora de Banos, Elba, Departmento de Recursos Pesqueros, Instituto Nacional de Pesca, Guayaquil, Ecuador. Personal commun., November, 1999.

[4] Luis, J., Biologist, La Pontilla, Mexico. Personal commun., March, 1999.

(Cruz, 1987a), and its males' sex products are white or cream colored while those of the females are orange (Cruz, 1987a; Fournier and de la Cruz, 1987).

In Ecuador (Altamirano et al., 1998) and other countries (personal commun., various fishermen), juvenile *A. tuberculosa* and *A. similis* are found attached by byssal threads to adult cockles and mangrove prop roots from July into September. *Anadara tuberculosa* and *A. similis* apparently grow from seed (probably 15–30 mm long) to marketable sizes within a few months. An experiment conducted in Ecuador with the cockles held in a submerged tray showed the time was 3–8 months (Mora de Banos[3]). Fishermen who were asked about this in every country confirmed this growth rate. They based this on observing seed in swamps where they were harvesting cockles and then observing harvestable-sized cockles in them a few months later. *Anadara tuberculosa* grows slightly faster than *A. similis*, and, in scientific tests, both grow faster if constantly submerged in water (Bravo and Abarca[5]).

Baqueiro (1980) reported on population densities of *A. tuberculosa*. He dug them with a fork from four to six 1-m^2 areas in eight locations in Bahia Magdalena and Bahia de Las Almejas, Baja California Sur, Mex. He did not state how much commercial harvesting was being done at those locations, but based on the mean lengths of the cockles, they may have been lightly harvested if at all. The smaller cockles were not sampled, and thus the following values do not represent total densities. The mean densities/m^2 (followed in parentheses by the smallest cockle lengths taken at each location) were: 8.8 (16 mm), 23 (42 mm), 17.2 (36 mm), 15.5 (32 mm), 24.1 (24 mm), 12.2 (36 mm), 6.6 (40 mm), and 7 (18 mm).

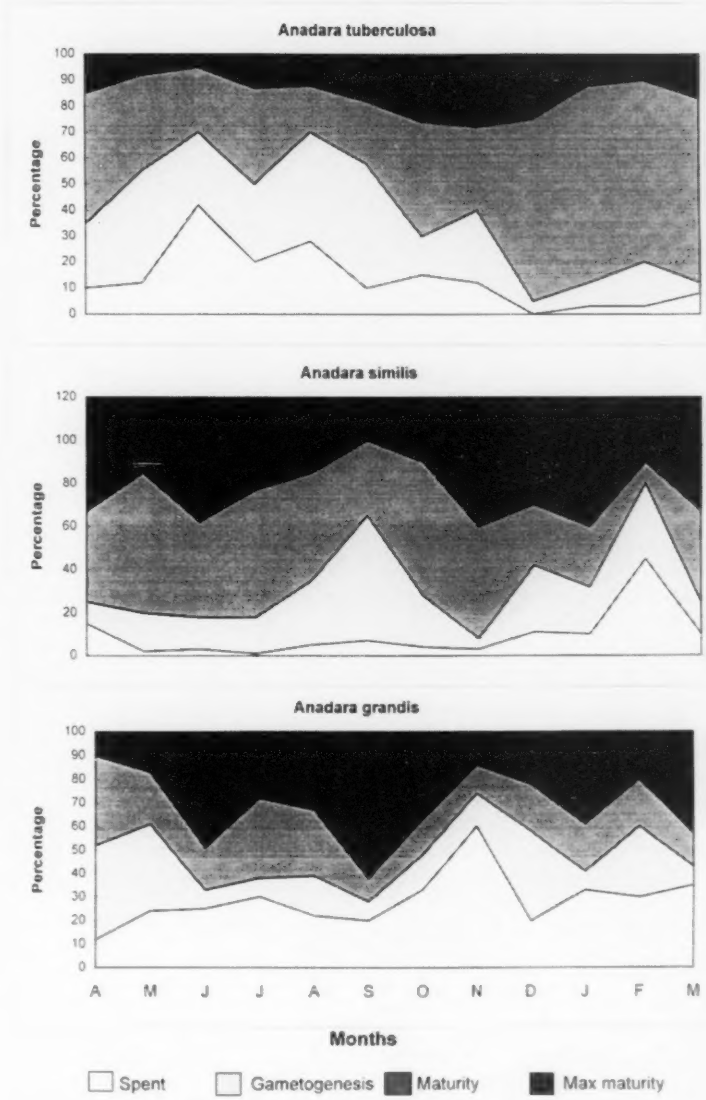

Figure 8.— The gonadal stages of the three cockle species, by month, in Costa Rica. The *A. tuberculosa* data are adapted from Cruz (1984a), the *A. similis* data from Cruz (1984b), and the *A. grandis* data from Cruz (1987).

Physical Setting and Human Life in the Cockle Fishing Villages

This section describes the lives of the fishermen[6] who harvest mangrove cockles from Mexico to Peru, but with particular emphasis on villages around the Golfo de Fonseca (El Salvador and Honduras) surveyed in April, June, and September, 2000, and January, 2001 after the fisheries in the other countries had been studied. The appendix describes my investigative methods. The main aspects covered were settings of the villages, economics, types of dwellings, personal possessions, water sources, food, marital unions and family

[5] Bravo, M., and N. Abarca. 1999. Potential de concha prieta (*Anadara tuberculosa*) en policultivo con camaron blanco (*Litopenaeus vannamei*). Unpubl. manuscr. Inst. Nacional de Pesca, Guayaquil, Ecuador.

[6] Cockle harvesting is done by people of both genders and many ages, from youth on up. The term fisherman covers all harvesters.

size, social life, schooling, medical and social care, and longevity.

Nearly the entire coastal region from Mexico to Peru is at low elevation, at most a few meters above sea level. Moderately warm temperatures (in the 80's in the afternoons), humid air, and gentle breezes prevail. It rains, often heavily, at least 2–3 times a week during the rainy season, which runs from May through November (but mainly September through November) in Central America, but from December through April in Ecuador and Peru. Rainfall is rare during the succeeding dry season. The landscape becomes green during the rainy season, but is brown, except for a few evergreen tree species, during the dry season. There are no recognized winter, spring, summer, and fall seasons, at least in Central America. The capital cities of most countries (i.e. Mexico, Guatemala, El Salvador, Honduras, Costa Rica, Colombia, and Ecuador) are located inland from the coast at much higher elevations, where temperatures are considerably cooler. The exceptions are Nicaragua, Panama, and Peru, where the capital cities are at low elevations.

The fishing villages in all the countries are located on or near estuarine shores, and most have fewer than 100 dwellings; some fishermen live in scattered dwellings along roadways. Access to the villages typically is via dirt roads 3–25 km from paved highways and often at much further distances from towns. The roads become muddy and have large potholes full of water during rainy periods, and they become rutted by truck and bus traffic. The ruts remain afterward.

Most residents, young and old, have always lived in their villages as had many of their parents and grandparents. Many are highly dependent upon the cockle resources for income and food, but finfish, shrimp, crabs, and in some places other such mollusks as oysters are also taken, and some residents have other types of employment besides fishing.

The fishermen are universally poor. Their living conditions are roughly similar in all the countries, although Honduras might have been slightly poorer as a consequence of Hurricane Mitch which destroyed some cockle harvesting areas and weakened the country's economy. The fishermen have little money and can afford only the barest necessities, including an extremely meager diet. Families in Honduran fishing villages survive on earnings of \$1.00–\$1.50/day. The proportion of families in most villages that makes its living harvesting mangrove cockles ranges mostly from about one-fourth to one-half, but it varies considerably. For example, one tiny village of 6 families in Mexico is entirely dependent on cockle harvesting, whereas in the port city of San Lorenzo, Honduras, less than 1% (about 30 families living along water's edge) of its population harvest cockles. In some villages, harvesting cockles is one of the lowest occupations in terms of prestige, because it is about the least remunerative.

The only documented data on job distribution in coastal villages is from Bravo (1994), who described village life in Bunche, Ecuador, where it was: cockle harvesting, 28%; harvesting post larvae of shrimp for farms, 28%; farm work, 14%; day labor, 11%; caring for animals, doing artisanal work, finfishing, and other jobs, 19%. Another type of employment for at least one family in nearly every Central American village is operating a tiny store that sells a few types of canned and packaged foods (such as potato chips), simple pharmaceuticals (such as aspirin), and soft drinks. The stores are located in the front room of their dwellings. Such dwellings have wooden walls with a 1 × 1 m opening at waist level facing the street through which sales are made.

During weekends, tourists from distant cities arrive in buses to visit the beaches of some villages, affording local residents an opportunity to sell cockles, home-cooked tortillas, potato chips, and soft drinks to them. In addition, some women make a few dresses for sale or wash neighbors' clothes to earn a little money. In Honduras, some village men work for sugarcane mills from December through early May, i.e. during the dry season, or in melon fields during all months except December and January (melon farmers get an average of 2.5 crops/yr) (Tay[7]). If married, their wives harvest cockles at this time. During the remaining months, the men harvest cockles with their wives.

Cockle fishermen do not have enough money to keep any in banks and have little money at home. Some are financially solvent by having sufficient money in reserve to pay for their food for a day or two, while some cannot make ends meet: Many are slightly in debt, perhaps by \$20, and others are in debt "up to their necks." Those deeply in debt can pay only the interest on the money owed. Some obtain food from the local grocer on credit.

However, nearly all Latin Americans, at least from Mexico to Peru, have little money (little passes through anyone's hands in a day) mostly due to scarce agricultural potentials and weak industrial bases in their countries as Guillermoprieto (2001) describes for Mexico. She said such poverty has people "living on the very edge of precipices."

A few factors keep the fishing villagers poor.

1) They must purchase all their food because the soil along the Pacific coast is so poor they cannot raise vegetables and root crops for themselves in family or public gardens. Soil humus seems to be totally lacking. Sachs et al. (2001) said that a) high tropical temperatures reduce soil organic matter to minerals and intense rainfall leaches them from the soil, b) the high temperatures also result in a rapid loss of soil moisture, and since precipitation is highly variable even during rainy seasons vegetable growing is difficult for that reason alone, and c) besides, diverse pests (insects and diseases [and also foraging pigs in fishing villages, author's addition]) can devastate crops. They also said that historically many attempts have been made to improve food output in the region but they have all ended in failure. The attempts were made first by the European colonists and more recently by donor agencies.
2) Villagers have few opportunities to earn money except by selling fish and cockles, both of which have

[7] Tay, Carlos, Quimicos Industriales, Grupo Disagro, Guatemala. Personal commun.

limited abundances and sell for low prices.

3) Most women have several children to feed and clothe. With the addition of each new child, the limited quantity of food available to a family has to be divided more finely among family members, and Sachs et al. (2001) said when women are pregnant they can do little work outside their homes to bring in money.

Tempering this poor economic condition of the villagers somewhat is their living in a consistently comfortable climate year-round and a naturally beautiful, nearly unspoiled tropical landscape. The villagers also appear to be free from robbery and other major crimes. They are friendly and are quick to smile and laugh. They desire relief from poverty, and some seek a richer life in the United States. But for many, the cockles will likely mean economic survival and some nutrition for the rest of their lives.

Figure 9.—A Honduran family supported by cockle harvests relaxing in their home near Puerto Grande.

Figure 10.—A typical fisherman's home in Honduras with walls of tree saplings.

Guillermoprieto (1994) describes dwellings, similar to most of those in the fishing villages, as "huts that represent the lowest rung of Latin-American poverty: dirt floors, no windows, wide gaps between uneven wall boards, a wood-burning hearth for cooking corn and beans. There is little else" (Fig. 9). Around the Gulf of Fonseca, the fishermens' dwellings are single level. Their walls are constructed of either: 1) cinder blocks or bricks held together with cement, which last many years; 2) tree saplings, 5–6 cm in diameter, which last about two years until the wood decays or a wind storm blows them over (Fig. 10); 3) tree sapling-mud walls which last for several years (the mud is packed between the saplings and dries hard); or 4) boards. The dwellings do not have windows and their roofs are constructed of orange tiles, palm leaves, plastic sheets, or corrugated galvanized iron sheets. Some roofs extend beyond the front of the dwellings providing the family with sort of a porch to sit and to cook their meals. Floors consist of hard sand or cement, or a combination of the two. Many families rent their dwellings for \$20–\$30/month. The adults, including married couples, sleep individually in hammocks which they wrap around ceiling beams out of the way during the day. As many as 3–4 small children and infants commonly sleep in a rudimentary bed along with their mother, and everyone sleeps in their day clothes. The yards around houses consist of sand rather than grass because the soil is nutrient poor and becomes too dry during the dry season.

Fewer than half the homes have electricity (power comes from large inland hydroelectric dams), and none have telephones. Electric power is used to light a plain bulb (which typically hangs loosely from a beam lying across the ceiling of one or two rooms, which are separated by a cloth or plastic sheet) and a tiny radio usually tuned to

Figure 11.—Cooking a tortilla on a typical stove in Honduras.

Figure 12.—Preparing tortillas for a family meal on stove made from an oil barrel in La Herradura, Baja California, Mexico.

a local music station. One home in San Lorenzo, Honduras, paid $1.00/month for its electricity.

Foods are cooked in pans on stoves constructed of a mixture of dried mud and sand. Their design is similar throughout the region (Fig. 11), but converted 50-gallon oil barrels are also used as stoves (Fig. 12). Most stoves are located out-of-doors yet under a roof. Thin tree saplings, cut about 2 m long, are the universal fuel used in the mud-sand stoves. Bundles of saplings are purchased for $1.00 each from men who cut them in wild public lands. A bundle lasts a household about a week.

Most villagers simply relieve themselves out-of-doors on the ground, using toilet paper ($0.027/roll), though some have outhouses. Pigs, which roam at will, root around in the feces for nutriment. If living near a beach, villagers wade into the water and relieve themselves there and clean themselves with the water while the currents carry away their wastes.

Fishermen have few personal possessions. Each house has 1–2 crude wooden tables, about three plastic or crude wooden chairs, several plastic bowls and dishes to prepare and serve food, and some have a few photographs of relatives and a drawing of a religious figure displayed on a wall. Adult clothing is purchased in second-hand stores in nearby cities. Women have about two good dresses to go visiting and marketing and three house dresses, while men have two pairs of pants and 2–3 sport shirts. Most adults wear sandals, while some go barefoot and others wear shoes. Fishermen do not have money to purchase such items as women's monthly sanitary napkins (a piece of cloth is used), eye glasses, hearing aids, vitamin pills, or cigarettes. Men and women have their hair cut by relatives or neighbors, usually for a small fee, such as $0.65, or for no cost.

None of the fishermen have automobiles, but some have bicycles. Nearly all walk, hitch rides on pickup trucks (the wait for one may be as much as 2 h), or take buses, which come once or twice a day, to travel from place to place.

At Christmas, parents give each of their daughters one new dress costing

about $10, and their sons get a new pair of pants and a sport shirt; this is the only clothing the children will receive in a year. Toys rarely are given due to a lack of money. The family and relatives share a Christmas dinner featuring tamales and fried chicken, which costs about $20. Families have to save money for about 1.5 months to pay for Christmas, by eating little food other than rice and beans.

In every village, some families own a pig or two and a few chickens, none of which are penned. A typical village has 10–20 pigs. Families could not provide enough food for them if they were penned, and so they let them forage around the villages to find scraps of food wherever they can. During low tides, the pigs also forage on intertidal mud flats. About every six months, a technician from the local health clinic inoculates most of the pigs, chickens, and dogs against diseases.

The fishermen do not have magazines or books in their homes, and they do not read newspapers. They rarely send or receive letters or other types of mail. Contacts with distant relatives can be made by using a public telephone present in each village. Any money from abroad comes to a local Western Union[8] office. Mail can be sent to a radio station, which announces over the air that mail for a specific person has arrived and then the person goes and gets it. The villages do not have movie theaters or other entertainment, except for television in some; most villagers have never seen a movie.

Nearly all households obtain water from public wells. It is carried home in plastic jugs and buckets, usually by children. In one town, the water from a public pump costs each household $1.30/month, the money being used to maintain the pump in operating condition. If residents purchase water from a neighbor, drinking water costs about $0.07/bucket while washing water costs $0.05/bucket.

The fishermen must harvest cockles or catch fish almost daily to obtain sufficient money for their bare necessities, spending nearly all of it on purchases of rice and beans, which constitute nearly their entire diet. If the fishermen do not harvest cockles to obtain some money, they cannot purchase any food to eat. Since cockle harvesting gains them only a little money, they can afford to eat chicken and less often pork or beef only about once a week; even rice is eaten in limited quantities owing to its expense. The fishermen receive little information about proper nutrition.

After being weaned from their mothers' milk, children rarely have milk to drink, and only then powered milk mixed with water. Breakfast for children and adults usually consists of a single item, such as a cup of beans, or 1–2 pieces of bread, or, once in a while, some fried fish, or an egg. Lunch usually consists of two items, perhaps 2 cups of beans and rice or a fried fish and 1–2 tortillas, or 1.5 cups of beans alone or with cheese. Dinner usually consists of a cup of beans and some rice, or 1–2 tortillas, or beans and tortillas; sometimes fish, cockles, an egg, or a thick slice of cheese or, when the fishermen have a little extra money, some chicken or pork may be substituted. But some families have just one daily meal, such as a large dish of boiled rice and chicken, or two meals of rice and beans and sometimes fish, and, for breakfast, coffee. The food is eaten from the plastic dishes with one's fingers or plastic spoons. Green vegetables and fruits, except for some mangoes and watermelon, are rarely eaten because they are not grown locally and are too expensive to purchase. The foods of the villagers lack essential nutrients to maintain them in good health and vigor. The children, being malnourished, are small for their ages relative to most children in the United States, Canada, and Europe.

When couples pair off to form households, the females typically are 14–16 years old while the males are 20–25 years old; by that age males have some gainful employment. The females "marry" because they are in love, want their own home and children, and are offered some financial support (gainful employment for them is scarce). Few such unions have a legal backing, few are united by a church ceremony, and many do not endure. The couple usually have children right away. Condoms (at $0.80 each) and birth control pills are too expensive to be used, and so women may have 3–5 children, but 6 and 7 are common, too. Abortion is rare because it is frowned on by the culture, condemned by the Catholic church, and is illegal. The large families also result because few activities are available for people to occupy their free time. In Honduras, families in villages with television sets have fewer children than those in villages without them (personal commun., several villagers). Nearly all babies are born at home with the aid of a midwife, though some are born in a local clinic. Boys do not wear clothes or sandals until they are about three years old, while the girls wear only panties until that age.

Fishermen spend much of their free time resting and socializing with their immediate family and neighbors, while their children play near them with simple objects (a bicycle wheel with no spokes is a common object). The villagers are used to being consistently amongst a group of relatives and neighbors from the time they are infants through their entire lives. Family relationships are close. (The villagers social lives contrast with those in many parts of the United States in which people live more solitary lives. Individuals feel lonely when isolated from such family groupings.) A typical daytime scene outside a fisherman's residence is a family group of 2–4 adults (a grandmother and her adult children), 6–12 school-age children (mostly girls 9–15 years old who do not attend school), besides 1–2 babies. There is consistent chattering and playing among the children while the adults discuss their family matters and also their quiet village life. Little happens in Latin American countries, and there is little national news to discuss—home life would amount to considerable boredom without the children.

The smallest children go to bed right after dark (usually around 6 p.m.) and awaken around dawn, 6 a.m. Where television is available, the older children, whose usual bedtime is around 8 p.m., remain awake until 9 p.m. to watch

[8] Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

soap operas. The 6–8 television programs shown are Mexican-made soap operas that feature beautiful women, dubbed shows from the United States, a wacky comedy, and 2–3 news stories that are usually about small national development projects, such as dwellings being constructed for the homeless, or disasters, such as a bus crashing, a river overflowing, or a landslide damaging homes.

Husbands appear to be less responsible than their wives, because they frequently spend some of their money to get drunk on beer (about $0.60/bottle). The heavy drinking helps them "to escape from their poor life and disappointments." Alcoholism is higher among male fishermen than among their counterparts living in inland towns due to their deeper poverty (Gonzalez[9]). On the other hand, women use their money for food and child care.

Besides, husbands often desert their wives and young children for good, seek relationships with younger women, and provide no further support. Caring for small children does not go with their macho nature, that features dominance of males over females. The mothers are "left with nothing," and have almost the entire burden of supporting themselves and their children. They are provided moral help and assistance in child care by an extended family of relatives and neighbors who can be in a similar circumstance, but they assist the others in child and elderly care. A family member with a little extra cash usually shares it with needy relatives. About the only work for most mothers and their older children is harvesting cockles.

To attend public grammar school, the children must have a uniform (in Honduras, a white blouse and blue skirt for girls, and a white shirt and blue pants for boys in accordance with the country's national white and blue colors), shoes, a backpack, separate notebooks for each subject, and pencils. Their purchase, at about $25/child, amounts to a relatively large expense for parents, and most cannot afford to send all their children to school. One or two typically are sent but few finish the six grades of primary school due to the expense, and some parents remove them to harvest cockles or do other work to bring in some money. Most school-age children, especially the girls, remain idle at home playing and doing a few simple household chores, such as fetching water from a well—there is little to do. Often, a child attends school for 2–3 years, drops out for a year or two due to a lack of money, and then, if the parents can afford it, returns to school. A child is able to read and write marginally after completing three grades of school. Perhaps half of the children never learn to read and write. A child of a cockle fisherman rarely can become a teacher or nurse, because his or her parents cannot afford that much schooling. Besides a lack of money, another reason for the low attendance at schools is a lack of jobs for adults that require reading, writing, or much knowledge.

Some schools have 3 rooms for the primary grades; as many as 65 children in 2 grades are seated in each room with 1 teacher. The teacher gives instructions to one grade, while the other grade does written work for about an hour. Afterward, she goes in front of the other group and instructs them while the first group does written work. The teacher alternates back and forth during the school session. In some areas, school class schedules are adjusted to the changing tide levels to allow the students to harvest cockles every day. If the tides are low in the morning, the classes are held in the afternoon, and vice versa.

Illnesses may be treated at home or in a local government-funded health clinic. When mildly sick, people consume chamomile tea, eucalyptus tea, or shark liver oil. For more serious illnesses, they go to the local clinic in or near their village for inexpensive medical attention. Doctors do not treat people in their homes. (In Honduras, the health clinic in Monjaras which serves at least 3 fishing villages (i.e. Cedeno, Puerto Nuevo, and Punta Raton) required traveling 8, 9, and 18 km, respectively.) Some medications are issued free by the clinic; people pay for others at a store. Children commonly have intestinal worms picked up by walking in their bare feet over pig feces. The clinics or their mothers give them pills or a powder mixed with water to kill the worms about once every three months. Diarrhea and mosquito-borne dengue and malaria are also contracted. If anyone is seriously ill and has to go to a hospital, he or she may have to borrow money from the neighbors to pay the bill and pay it back later with earnings from selling cockles. The fishermen have excellent teeth, probably because they do not have the money to purchase candy, cookies, or fruits. Some brush their teeth regularly.

Honduras and El Salvador have no public support (welfare) for destitute citizens. Villagers are "on their own;" grown children have to take care of their elderly parents and infirmed relatives, and families often band their resources together to aid any members in desperate need. Gonzalez (2001), a newspaper reporter restating comments by a visiting researcher from the United States, said officials in Central American governments have little concern and respect for their country's farmers (and this applies to fishermen as well). The officials do not have any tradition for providing rural services, because they do not see the payback in human terms but rather in production goals. From my experience of interviewing fishery and environmental officials in these countries, they view their country's fisheries and environments in the same way: production statistics and environmental protection, but without concern for the fishermens' lives.

Data are unavailable on the average longevity of people in the fishing villages, but 2 interviewed religious leaders (Gonzales,[9] Valladares[10]) believe it is shorter than the established national figure of 62 years of age in Honduras (Targ and Brill, 1995) because the fishermen live far from towns where people have closer access to food, medical attention, and medicines. A funeral costs about $200 (for plain wooden casket, clothes for the dead person, and bread and coffee for relatives and neighbors).

[9] Gonzales, Florentino, Catholic priest of Marcovia area, Monjaras, Honduras. Personal commun., September, 2000.

[10] Valadares, Jesus Francisco, Catholic priest, Catederal Choluteca, Honduras. Personal commun., October, 2000.

Its cost often is shared by the village community.

"El Telegrafo," a newspaper in Guayaquil, Ecuador, published an article by Manuel Bravo (1994) that described similar life conditions of the cockle harvesters of DeBunche in the province of Esmeraldas, Ecuador. The adults there did not finish school and more than half were illiterate. The women marry at a young age and their husbands are 7–9 years older. In that village, all adult cockle harvesters were women, each of whom had 4–5 children. The village had 51 adults and 28 minors ages 8–13 who harvested cockles with their mothers during school vacations. Most harvesters were 20–40 years old, but their overall age was 8–70 years. Bravo believed the women were more responsible to their families than were the men, because they earnestly harvested cockles to earn money to feed and clothe their children. The preschool children were left in the care of neighbors and relatives while they were harvesting. For most fishermen, cockle harvesting brought the only income to their homes, but some also kept pigs and chickens to sell. Nearly all their earnings were spent on food. To keep the residents from abandoning DeBunche, Bravo recommended that a pharmacy and an agency which provides health seminars be established.

Javier Rosero[2] said that in the cockle harvesting communities of the same Esmeraldas Province in Ecuador, about 75% of the people are listed as extremely poor, only 30–44% receive health services from public clinics, and about half the women do not receive any medical attention while they are pregnant or giving birth. From 38% to 43% of children attend the first 2–3 grades of school.

O. G. Plaza[11] describes a similar condition of life among the cockle fishermen in Colombia. The fishermen comprise the lowest economic group in the Tumaco area; their only source of income is cockle harvesting. Their houses have a poorer quality than those in urban areas, most fishermen are illiterate, the few who can read and write finished only 3 years of primary school, and more than 75% of the people have no subsidiary health care.

[11] Letter from O. Gustavo Plaza, Microempresarial, Tumaco, Colombia, dated April 4, 2000.

Figure 13.—Some mangrove cockle fishermen in A, Mexico; B, El Salvador; C, Costa Rica; D, Honduras; E, Panama; and F, Ecuador.

Table 1.—Estimated numbers of fishermen harvesting mangrove cockles daily when conditions allowed it in each country.

Country	No.
Mexico	645
Guatemala	235
El Salvador	2,850
Honduras	225
Nicaragua	160
Costa Rica	500
Panama	220
Colombia	5,000[1]
Ecuador	5,055
Peru	75
Total	14,965

[1] This estimate could be low.

Table 2.—Local names for the cockle, *A. tuberculosa*, in each country (*A. tuberculosa* is referred to as the male cockle and *A. similis* is referred to as the female cockle).

Country	Local names
Mexico	
Baja Calif.	Pata de mula
Mainland	Pata de mula, almeja negra, almeja candelon, almeja canaval
Guatemala	Concha negra, curile
El Salvador	Concha negra
Honduras	Curile, curile negro
Nicaragua	Concha negra
Costa Rica	Piangua
Panama	Concha negra
Colombia	Piangua
Ecuador	Concha, concha prieta (also piangua, sangara)
Peru	Concha

Cockle Fishing

Over the entire cockle range from Mexico to Peru, about 15,000 fishermen actively participate in the harvests (Fig. 13; Table 1). The trade employs a variety of common names for the cockles, some being unique to a country while others are more universal (Table 2). Harvests in all countries usually run about 15–20 days a month. The days missed are during neap tides or heavy

rains when harvesting is difficult or impossible, and in some countries no harvesting is done on Sundays. Also, women usually wash their family's clothes one day a week.

The governments of some countries have a regulation regarding the minimum harvestable size of *A. tuberculosa* and *A. similis*, to prevent the harvest of immature cockles and maintain adequate spawning stocks. The minimum harvested length appeared to range from about 47 to 60 mm, depending on the country (personal commun., various fishermen), but some cockles under 60 mm are taken. The harvests are rarely, if ever, checked for sizes by government wardens, perhaps because cockle reproduction does not appear to be threatened anywhere by low spawning stocks, and the markets do not want small cockles. The smallest cockles bring the lowest prices because consumers get the least quantity of meat from them, so market demand affects the sizes harvested.

The cockle harvesting areas usually are 1–4 km or even farther from the villages. In part because of this distance and the estuarine waters of the harvesting areas intermix with clean Pacific Ocean waters, the cockles appear to be uncontaminated by domestic pollutants. No mention anywhere was made of human illnesses caused by eating cockles.

In every country, men and women harvest cockles, but children as young as 7 years old commonly join their parents as harvesters. The oldest male fisherman interviewed was 87 years old (in Honduras), the oldest female harvester was 72 years old (in Panama). Many are lifelong cockle harvesters, though they have to quit when their health (often eyesight) fails.

The fishermen harvest cockles during low tides when they can walk in the mangrove swamps. They spend about 4 h/day harvesting, and since the tidal cycle advances about an hour each day, the working hours advance by that much each day. The fishermen reach down and feel in the mud for the *A. tuberculosa* and *A. similis*. They find most *A. tuberculosa* near the bases of the mangrove prop roots. Their hands penetrate the mud to their wrists for *A. tuberculosa* (Fig. 14) and commonly to their elbows for *A. similis*. They find an *A. tuberculosa* every several probes. The *A. grandis* are spotted sticking slightly out of the muddy sand. During the part of the day when the tides are too high for harvesting cockles, the men often try to net some finfish in the lagoons. In some areas, cockle harvesting is seasonal, alternating with catching finfish or shrimp, or working as farmers in sugarcane and melon fields.

Cockle harvesting is not difficult or onerous, because it does not involve any heavy lifting. Cockles are harvested in the cool shade under the mangrove canopies, and the fishermen are autonomous, but it is unpleasant walking and probing in soft mud. As they walk to a new place, stop, and reach around some aerial prop roots for cockles, their legs may sink in mud half way to their knees, and much effort often is expended squeezing their bodies between the roots to gain access to places where they can get cockles. Some groups of prop roots are too densely spaced for fishermen to penetrate.

The fishermen have a short walk from their homes to their boats and then a 30–120 min boat run to harvesting areas. Nearly all fishermen travel to and from the cockle harvesting areas in wooden canoes (6–7 m long, 0.75 m wide) or fiberglass boats (4.75–6 m long). The canoes, which usually last 3–6 years, are propelled by using wooden paddles or by small outboard motors, while the fiberglass boats, called "pongos," are propelled by outboard motors. A group of 2–5 people, usually family members, two of whom paddle, go together in the canoes (Fig. 15), though some fishermen go in them alone. The pongos carry 6–10 (but sometimes more) people.

The persons who operate the pongos drop off the fishermen, one at a time, along the mangrove banks and pick them up about 4 h later to return home (Fig. 16). They go to a different area each day, leaving harvested sites alone for about 7–14 days to allow the cockle seed to grow. They do not know whether anyone else may have harvested there while they were gone. If the cockles are scarce, they move to another location. Nearly all the fishermen harvest cockles to sell, but some harvest them only for their own food.

The fishermen's expenses are small. If a person or family does not own a canoe, they pay the owner a small amount, commonly about 25 cockles/day from each person's harvest, to take them to and from the harvesting areas in a canoe or pongo. Many go barefoot when harvesting cockles, but some wear tennis shoes, heavier shoes, or boots. Fishermen usually harvest barehanded, but some wear gloves, and some in Peru wear cloth tubes tied onto each finger (Fig. 17). Net or cloth baskets or sacks (Fig. 18) or small plastic buckets are used to hold the cockles during harvesting.

Biting insects are universal pests, and mosquitos can be abundant during the rainy season. Fishermen repel them with sprays, creams, or petroleum (mixed with butter so it will not burn) applied to their skin, or by using smoke from a burning a bundle of palm branches, dry cow or horse dung, incense held in one hand, or, in El Salvador, with smoke from hand-rolled cigarettes, or, in Honduras, from inexpensive cigars.

A danger in Ecuador are fishes with the common name pejesapo (Eleotridae and Gobidae families), that are buried in the mud. A fisherman can get a pejesapo bone stuck in his or her arm, foot, or leg, causing pain, swelling, and fever. Cockle fishermen also get swollen hands and feet and itchy skin even without interacting with fish (Rosero[2]). Besides, some prop roots are covered with animal growth which can cause skin abrasions if the fishermen rub against them.

After harvesting, the fishermen return to their boats, slosh their cockles in the water to wash off the mud (this may also be done back at the village shore), go back to their villages, often set 1–2 dozen cockles aside for home use, and then take the remainder to dealers in the villages or keep them at home until a dealer comes for them. The fishermen rest and socialize in the mornings when tides are low in the afternoons, or in the afternoons when tides allow them to harvest in the mornings.

The dealers save some cockles for sale to neighbors and then pack the remainder whole in bags, usually about

Figure 14.—Reaching for *Anadara tuberculosa* amidst mangrove prop roots, *Rhizophora mangle*. Top and middle photographs were taken in Esmeraldas Archipelago (near the Colombian border), Ecuador; photograph at lower left is from Puntarenas area, Costa Rica.

500–1,000/bag, for delivery by pickup trucks or public buses to market brokers in population centers 2–3 times a week. Ice is not used in transit because its cold temperature would kill the cockles, but they are kept out of the sun. The brokers sell them to merchants in central markets and street markets and to restaurants (Fig. 19).

Anadara tuberculosa survive out of water about 5 days during warm periods and 8 days during cool periods before gaping and dying. *Anadara similis* live half as long and consequently usually bring the fishermen about half the price of *A. tuberculosa*. In the trade in most countries, *A. tuberculosa* is referred to as the male cockle, while *A. similis* is referred to as the female cockle (this has nothing to do with the actual gender of the cockles), but sometimes they are referred to as the black cockle and the white cockle, respectively.

Figure 15.—Group of four fishermen on their way to mangrove swamps to harvest cockles in the Esmeraldas Archipelago, Ecuador. The paddler in the bow is their chauffeur, who will be paid in cockles (25 from each fisherman) for his service. The youth at the stern is along for the ride.

Figure 16.—Group of five Ecuadorean fishermen walk toward cockle harvesting areas that are amidst mangrove prop roots, *Rhizophora mangle*.

The fishery for *A. grandis* is relatively small, and it was not surveyed except when noticed while surveying the fisheries for the other cockles. *Anadara grandis* can be spotted sticking slightly out of the mud on flats (Fig. 20). Piles of *A. grandis* are placed alongside the piles of the other cockles and sell at a higher price per cockle in markets. People prefer them because they are easier to open and have more meat, although the *A. tuberculosa* are tastier. *Anadara grandis* are cut in half when prepared in seviche (cockle meats, juice of limes, *Citris aurantifolia*; and condiments), whereas the meats of *A. tuberculosa* and *A. similis* usually are served whole in seviche. It appeared as though *A. grandis* quantities had declined in all countries due to intense harvesting, and the Federal governments in Costa Rica and Honduras have banned their harvests to protect them.

Central markets in cities sell a large variety of produce (root crops, tomatoes, green vegetables, fruits) as well as fresh pork, beef, chicken, and fish, and, commonly, cockles and mussels, besides clothing and other goods. In the largest cities, the central markets usually are located within an enclosed building which occupies an entire block. Most produce is sold in large bins, while the meats, fish, and bivalves are displayed on tables. Vendors stand beside the bins and tables to serve customers. On streets along the sides of the main building, other vendors set up stands to sell similar produce. In addition, small food stands on various corners of city blocks (Fig. 21) and small stands at tiny resort areas (Fig. 22) frequently specialize in cockles. Most serve them raw on the half-shell with lime juice. Restaurants usually open the cockles with a short, but wide knife fastened at one end by a swivel nut (Fig. 23).

Written histories of the cockle fisheries do not exist in any country. Nevertheless, Elba Mora de Banos[3] believes the fisheries undoubtedly are several centuries old. She believes that, in the 1800's, cockles were eaten in local villages, and, where possible, they were taken to distant population centers that were on or near the coasts on small sailing vessels. Her beliefs are partially substantiated by many fishermen who stated that their parents and grandparents had harvested cockles, while others were land farmers.

Figure 17.—Cloth tubes tied onto fingers protect this Peruvian cockle fisherman from cuts. His cockles are in the bag (R).

Cockle Fisheries by Country

Mexico

In Mexico, cockles are harvested in Baja California Sur and between Guaymas and San Blas on the northern part of the mainland's west coast (Fig. 24). The principal species harvested is *A. tuberculosa*.

Baja California Sur

Anadara tuberculosa are harvested along the west coast of Baja California Sur[12] in Laguna de San Ignacio, Canal Soledad, Bahia Magdalena, and Bahia de Las Almejas, extending over a north-to-south distance of 335 km^2. Lightly harvested, the cockles are underexploited and some even unexploited in many mangrove swamps. Fishermen live in Campo Rene, La Laguna, San Buto, Puerto Adolfo Mateos, Santo Domingo, La Herradura, Puerto Cancun, and a few smaller villages. In the entire Baja California Sur, about 85 men, women, and children harvest cockles: 45 in the Laguna de San Ignacio area and 40 in the 3 areas further south. Hernandez-Valenzuela (1996) reported that *A. tuberculosa* also occurs in small mangrove swamps on the east coast of Baja California in the Gulf of California, but the fisheries there are tiny or nonexistent.

Figure 18.—This Ecuadorean will light the bundle of coconut branches to produce smoke that repels biting insects while she harvests cockles, placing them in her mesh basket.

Entire families harvest cockles nearly year-round, 4–6 days a week, but rarely on Sundays. Individual daily harvests usually range from 500 to 1,000 cockles/day, but can be as many as 1,200 cockles (Fig. 25). Cockle fishermen here feel they are doing well, because they can earn at least $10/day. In comparison, local farm workers earn about $4 in an 8-h day.

Baja California Sur has four cockle dealers, three of whom buy from the fishermen in the Laguna de San Ignacio area, and one buys from the fishermen in the south. The dealers have agreed amongst themselves on prices they will pay and to divide the area into territories, and each purchases cockles only in his own territory.

The dealers have calendars marked with daily tidal cycles (Fig. 26). Each day when the calendars show the tide is rising, they drive their pickup trucks to the villages, arriving when the fisher-

[12] Information for this section was obtained from several individuals; the principal source was Manuel Davis, cockle dealer, Concepcion, Baja California.

Figure 19.—Advertisement for the Costa Rican restaurant, Bar "El Rodio," which specializes in serving cockles (Espec. en pianguas).

Figure 20.—Harvesting an *Anadara grandis* on a muddy flat at low tide in the Archipielago de Las Perlas, Panama.

men are landing their boats and cockles. The fishermen pack the cockles in bags, 500 cockles per bag, each bag weighing 35–40 kilos. The four dealers purchase about 4 t of cockles a day and ship them to markets every second day.

The three dealers in the north take their cockles on pickup trucks northward to Ensenada and Tijuana in Baja California Norte. The dealer in the south ships his to the mainland. He takes the cockles to his home in La Constitucion, stores them in his garage for 1–2 days, and then sends them via pickup trucks to La Paz for ferry transport to Mazatlan. From there, they are trucked to brokers in Guadalajara and Mexico City. It takes 2.5 days to get the cockles from La Constitucion to Mexico City. The total shipping cost is $5.38/500-cockle bag. The cost of shipping them by air from La Paz to Mexico City, at about $240 per 40-kilo bag, is prohibitive.

One unusually large family of 12 (father, mother, and 10 boys and girls, the youngest of whom was 5 years old) live in a tiny village or "camp" with 5 other cockle-harvesting families at a location named La Herradura, which began as a cockle harvesting area in about 1990. The father and the 10 children usually harvest cockles every day, using 2 pongos to take them to and from the harvesting areas. The dealer drives there every 2 days to pick up about 25 bags of cockles at a time and leave sales slips with the father. The dealer pays $0.02–$0.025 for each cockle, or $10.00–$12.50/bag. Each fisherman harvests about 35,000 cockles/month.

During 1991–95, from 446 to 885 t/year of *A. tuberculosa* were landed in Baja California Sur. Production varied due to market demand (Hernandez-Valenzuela, 1996).

Mainland

The Pacific coast of the Mexican mainland[13] has a series of large lagoons

[13] Information for this section was obtained from interviews of 3–8 people in each village; the principal sources were Manuel Lomeli in San Blas; Jorge Avila in Villa Hidalgo; Berta Perez Gonzalez in Tepic Nay; Emilio Cega in Palmar De Cuahulla; Maria Theresa Olivas Dramos in Dautillos; Jose Luis in La Pontilla; Maria Dolores Lopez Solorrano in Navolato; and Jorge Castro Florez in Playa Colorado.

that occupy almost 80% of the 850 km distance between Guaymas and San Blas, and 3 large lagoons, Laguna Superior, Laguna Inferior, and Mar Muerto, on its south coast. The lagoons between Guaymas and San Blas contain mangrove swamps and *A. tuberculosa* and *A. grandis*, but the three large lagoons on the south coast contain neither. Mangrove swamps and cockles also do not exist along the 550 km stretch of coastline northward from Guaymas to the apex of the Gulf of California. The many villages near the lagoons between Guaymas and San Blas are located along unpaved roads 6–20 km from Mexican Highway 15.

Figure 21.—An open-air restaurant which serves cockles, oysters, and other seafoods in Tuxpan, Mexico.

Figure 22.—Opening an *Anadara tuberculosa* to be eaten raw on the half-shell at an eating place on an El Salvador dock.

Anadara tuberculosa between Guaymas and San Blas are harvested, but the effort here, too, is relatively light because the market is weak: Mexicans do not eat many cockles. About 560 fishermen harvest cockles along this coast: 1 in Gusimas, about 4 in Pablado Cinco, 50 in Las Guillas Margen Derecha, 20 in El Colorado, 20 in Topolobampo, 100 in Huitussi, 20 in El Tortugo, 8 in Palos Verdes, 5 in Playa Colorada, 45 in Costa Azul, 75 in Dautillos, 45 in Las Aquamitas, 15 in El Castillo, 15 in El Conchal, 20 in Cospita, 40 in La Pontilla, 40 in Palmar de Cuautla, 20 in Rancho Nuevo, 10 in Javier, and 4 in San Blas. They also seek finfish, shrimp, and crabs, with fish and shrimp being the most important. They harvest cockles mainly from February to March into July–August and net shrimp and fish during the remaining months, though some cockle harvesting always occurs. Some people only harvest cockles for personal consumption.

Most cockle harvesters are men; the percentage of women harvesters ranges from occasional participants in the village of Las Guillas Margen Derecha to about 25% in Las Aguamites. Some children harvest on weekends and during summers starting at the age of about 10, at least for boys.

Most fishermen paddle to the harvesting zones in canoes or use outboard-motor-propelled pongos. Pongos take groups of 5–7, with each person sharing the cost of gasoline or paying the boat owner \$0.50–\$1.00 a day. Some dealers pay for the gasoline used by the poorest fishermen. The remaining fishermen ride to harvesting zones overland on bicycles or on horses and then walk into them. Harvesting is done on average 3–4 days a week (5–6 days in one week, and 1–2 days in the following week due to changing tide conditions), and about 15 days a month. This includes harvesting on Sundays. The fishermen sometimes go long distances from their villages to

where the cockles are most abundant to obtain larger harvests. They camp out on high ground near the mangrove swamps, making a shelter of branches or a sheet of plastic. Their meals consist of fish, beans, and rice, which they bring with them, and some cockles.

Daily individual harvests are relatively large compared with those in the other cockle-producing countries, ranging from 400 to 600 cockles, but they can go as high as 1,000 cockles or more. The dealers pay fishermen \$2.15–\$2.75/100 cockles (\$0.022–\$0.028/cockle) and tell them how many cockles they will need in the next few days. If a dealer will need 5,000 cockles, 5–6 fishermen will harvest; if he needs more, more fishermen will harvest. Cockles from this region are sold in Tijuana, Mexicala, Hermosillo, Ciudad Obregon, Culiacan, Mazatlan, Guadalajara, Mexico City, and other population centers.

One dealer in Palmar de Cuautla buys cockles from 10 fishermen. Two or three times a week he makes day trips on a bus northwestward to Tecuela, a distance of 17 km, taking the cockles, 1–3 sacks (1,000 cockles/sack) at a time. The trip each way takes about 1.5 h and the bus costs him \$1.50. He sells the cockles in Tecuela for \$3.75/100 (\$0.038/cockle) to three brokers, who take them on pickup trucks to restaurants and street vendors for sale.

The cockles are eaten in seviche, boiled with rice, or raw on the half-shell with condiments or lime juice. Some eating places put live, unopened cockles in pans heated by a flame. The cockles open, their top shells are removed, and their meats are served in the lower shells with a lime. In cities such as Tuxpan, several small open-air restaurants serve cockles to customers raw on the half-shell with a lime (Fig. 27). The waitresses open cockles by repeatedly striking the edge of the shell with a knife to break a hole in it and then inserting the knife to cut the two adductor muscles away from the upper valve. Each restaurant sells 100–500 cockles/day. Taverns also sell raw cockles on the half-shell with a spicy sauce and lime juice with drinks.

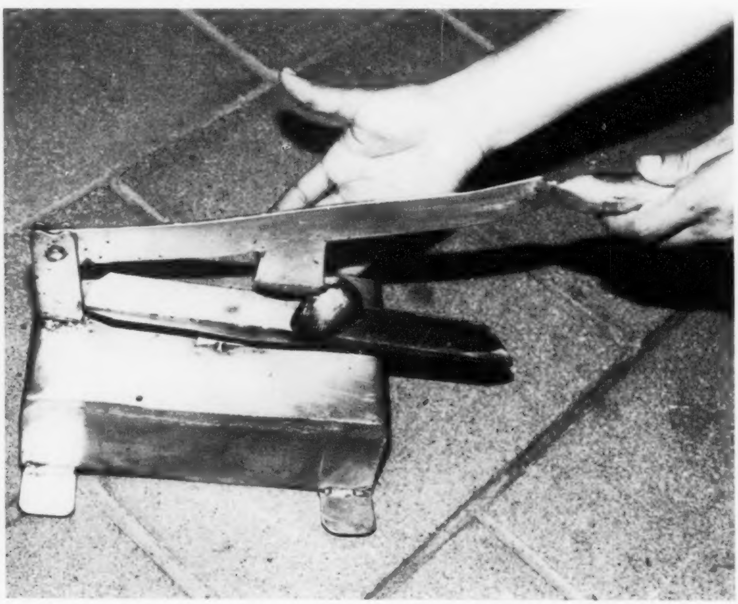

Figure 23.—An anvil-knife for opening cockles; cockle blood runs down a groove and collects in a bowl (not shown). This type of opener is common in most cockle-producing countries.

Anadara grandis *in Mexico*

On the Mexican mainland, *A. grandis* is harvested fairly intensely in only Ensenada Pabellones, a bay 40 km south of Culiacan. Fishermen from the villages of Las Puentes and Las Arenitas gather them from March through August. (They seek shrimp during the remainder of the year.) In Las Puentes, about 60 men out of 300 total fishermen harvest *A. grandis.* Each harvests for 3–4 h and gets as many as 300 *A. grandis*/day. A sample from a fisherman's harvest averaged 70 mm long (range, 62–77 mm). The fishermen were paid about \$10.75/100–150 (\$0.07–\$0.11/cockle) for them. In Las Arenitas, 70–80 fishermen regularly seek *A. grandis.* Each gets about 100/day, a bucketful, and gets \$8–\$9 for them. They harvest for 7 consecutive days, take 4 days off, and then repeat this work-rest cycle. No one there normally harvests *A. tuberculosa* though they are abundant, because no one will purchase them when *A. grandis* are available. The fishermen harvest *A. tuberculosa* only when they cannot find many *A. grandis.* The fishermen eat some *A. grandis* at home in cocktails with tomato, lime, catsup, and onion.

Guatemala

Some small estuaries with mangrove swamps and *A. tuberculosa* indent the entire coast of Guatemala[14] (Fig. 28). They have only local names; the communities near them are Tilapa, El Chico, Manchon Muchual, Sipacate, and the four communities (Casas Viejas, Las Vivas, El Ahumado, and Barra del Jiote) in the Las Lisas area. About 235 fishermen harvest cockles daily in the country. Las Lisas is the most important area with about 200 fishermen. Entire families harvest when the children are not in grade school. The schools are in session from 7 a.m. until 12 noon, and, whenever the tides are low in the afternoon, parents bring along their children to help harvest. If the male fishermen are harvesting in the mangrove swamps during

[14] Information for this section was obtained from interviews of 3–8 people in each village; the principal sources were Jose Domingo Cortez and Carlos Enriques in Las Lisas; Very Alberto Cambera in Las Vivas; and Pedro Estrada and Oscar Martinez in El Ahumado.

Figure 24.—Shaded areas of the Mexican coast show cockle harvesting regions.

lunchtime and they are hungry, they often eat some mussels that are attached to the aerial prop roots, breaking them open with their teeth to get at the meat. From 70 to 100 cockles/day typically are harvested/person, while the best fishermen may take 110 to 130 cockles/day.

Dealers pay \$0.83–1.00/dozen cockles (\$0.07–\$0.08/cockle), and they sell them to brokers for \$1.00–\$1.17/dozen (\$0.08–\$0.10/cockle). The brokers take them to cities, mainly Guatemala City, the capital, on pickup trucks, using no ice, and sell them whole to restaurants and retailers. From Las Lisas, the trip to Guatemala City is 130 km and takes 3–4 h. Brokers get them there the day after the cockles are harvested. They also sell cockles to their neighbors, a dozen or two at a time. Dishes of seviche or boiled rice and cockle meats are prepared with them. Markets in Guatemala City also import some cockles from Panama and El Salvador which also arrive on pickup trucks. Upscale restaurants in Guatemala City charge \$4 for small serviches and \$13 each for the largest. In small local markets, cockles sell for \$1.33–\$2.50/dozen (\$0.10–\$0.21/cockle).

Anadara grandis *in Guatemala*

Guatemala has a small fishery for *A. grandis,* most being harvested from intertidal flats. In a typical day, each fisherman harvests 1.5–3 dozen and also may net some finfish. In a river near Champerico, five teenage boys were observed harvesting *A. grandis* that were growing along the river bottom at water depths of 2–3 m. The boys, who used a face mask and towed a 2.5 m canoe with

Figure 25.—Young harvesters carry cockles from the boat up a Baja California, Mexico, shore.

Figure 26.—Mexican dealer in La Constitucion, Baja California, Mexico, examines a calendar marked with tide levels to determine when to pick up cockles at the shores.

Figure 27.—A knife is used to crack the edge of an *Anadara tuberculosa* for removal of its upper valve; meats will be served raw on the half-shell with a lime on plate at left in Tuxpan, Mexico.

a light line from their waists, dove to the bottom and felt through the muddy sediments for them with their fingers. When successful, they brought up an *A. grandis* each dive and put it in their canoe (Fig. 29). Each boy usually harvests about two dozen/day and sells them for $1.70/dozen ($0.14/cockle).

Near the diving boys, a woman was standing at low tide beside and facing the sloping river bank lined with mangrove trees, the water level being slightly above her waist. She was reaching through the prop roots and harvesting *A. grandis* and *A. tuberculosa* in the muddy bank. She wore two dresses tied tightly at her waist; she put the cockles between the dresses and they collected at her waist.

El Salvador

El Salvador[15] has by far the largest number of cockle fishermen in Central

[15] Information for this section was obtained from interviews of 3–8 people in each village; the principal sources were Maria Guadalupe Moran in Zagote; Maritza Granadeno Climaco in La Herradura; Rosa Castro in Puerto Abalos; Rodrigo Saloman Romero in La Parada; Jose Emilio Martinez and Felix da Jesus Logano Sanchez in Puerto Parada.

America, a total of about 2,850. The major harvesting area is Bahia de Jaquilisco located near the center of its coast, and about 2,000 people harvest cockles in its mangrove swamps daily. The remaining areas are a lagoon near the city of El Zapote with 200 active fishermen, Estero de Jaltepeque with 350, and the Golfo de Fonseca with 300 (Fig. 30).

Cockle resources in El Salvador are under heavy fishing pressure due to the large number of fishermen, and individual harvests are relatively small. Each adult fisherman usually takes 50–75 cockles/day when the tides remain low, and about 40/day during neap tides or when it rains steadily; the children harvest about half as many. As elsewhere, the fishermen lead a close "hand-to-mouth" existence (Fig. 31).

Many children harvest with their parents. School sessions are arranged so that the children can harvest every day. If the tide is low in the morning, then the school session is in the afternoon. When the tide is low in the afternoon, then school is held in the morning.

Cockles are sold here by the "basket" (60 cockles) rather than by any of the groupings used in the other countries. The dealers pay \$3.00–\$3.80/basket (\$0.05–\$0.06/cockle), and then sell them for \$3.45–\$4.15/basket (\$0.056–\$0.07/cockle).

Individual dealers buy cockles from as few as 10 to as many as 50 harvesters. Most dealers sell the cockles to brokers who ship them to cities, such as San Salvador, the capital, or take them to restaurants. One dealer in La Herradura, near the estuary of Estero de Jaltepeque, purchases cockles from 22 fishermen in Triunfo and 8 fishermen in Puerto Parada. He loans boats and motors to some fishermen so they will sell cockles to him, and he sometimes loans them money a day or two ahead. If the fisherman does not come through with the cockles or return the money, the dealer has to drop him as a seller. His principal markets are 2 restaurants in Acajutla and 5 restaurants in San Salvador; each buys about 200 cockles/day from him. The rest of his customers come to his house and buy 1–2 dozen at a time.

Fishermen from the town of Puerto El Triunfo harvest around the islands of Madresal and Isla de Mendes in the Bahia de Jaquilisco. One major cockle landing site is a large dock, about 8 m wide and 200 m long. The dock is paved, handles trucks, and points into the bay like a large finger. Every day, about 20 dealers (men and women) wait along its sides, each at the same site, for the fishermen to return with their cockles, each buying from 10 to 25 fishermen. Some dealers rent dugout canoes with paddles to the fishermen for \$0.70/day; when more than one fisherman goes in a canoe, they divide the rent cost among themselves. Some of the dealers also loan money to the fishermen 1–2 days in advance. The fishermen return with 1–2 baskets each on most afternoons, but with only about 40 cockles on days with unusually high

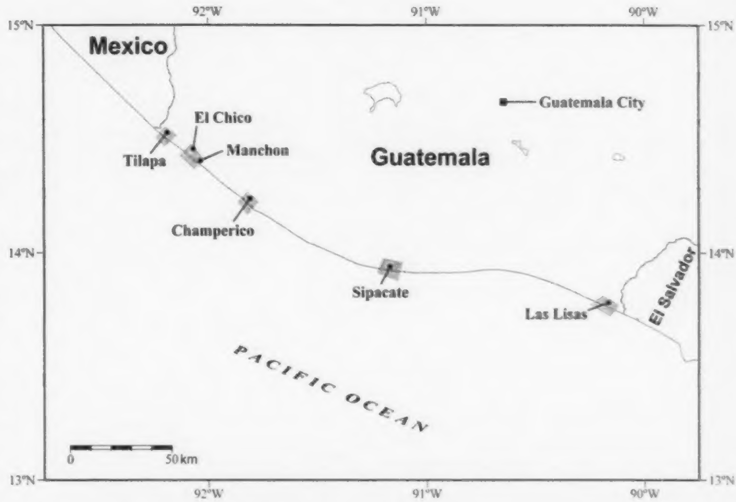

Figure 28.—Guatemala's Pacific coast showing areas where cockles are harvested.

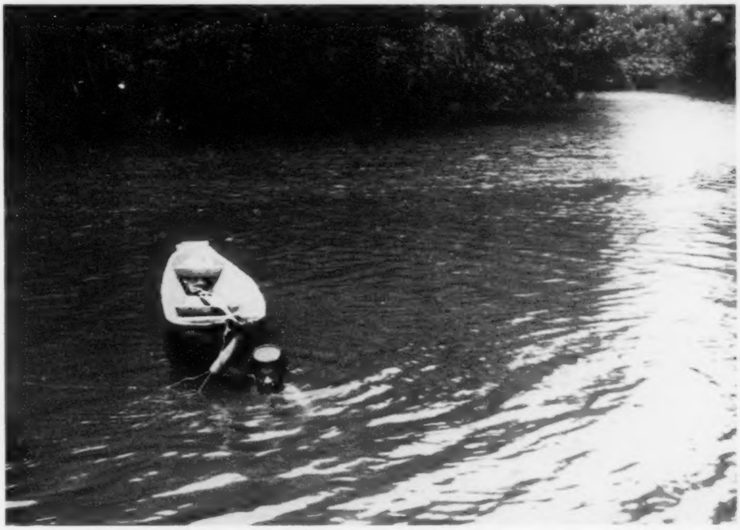

Figure 29.—A fisherman rests by his canoe after diving for *Anadara grandis* near Champerico, Guatemala.

tides. The dealers count the cockles into bags and then pay the fishermen at the rate of \$3.50/basket (\$0.06/cockle) (Fig. 32). A typical dealer buys about 25 baskets (1,500 cockles) a day and packs them into 2-bushel bags. Nearly all the cockles are shipped to San Salvador on public buses the following day. The cockles are loaded onto the buses in the early morning, which leave around 4:30 a.m. to avoid the sun, and arrive 2 h later. The bus driver delivers the cockles and brings back the money to the dealer, who is paid \$4.00/basket for them. The driver charges about \$1.45/bag for this service.

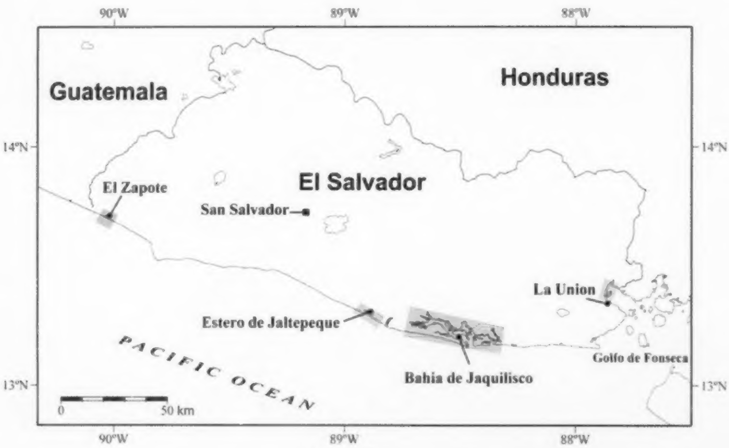

Figure 30.—El Salvador's cockle harvesting areas.

The largest port on the Golfo de Fonseca is La Union. From there and nearby El Salvadorean villages, about 65 boats with 300 fishermen leave to harvest cockles along the gulf's western shores, most of which belong to Honduras. (Some resentment exists among Honduran fishermen about Salvadorean fishermen harvesting cockles in their country.) The immediate area of the city has 13 cockle brokers. One broker buys from 7 dealers, who in turn collectively buy from 20 harvesters. This broker stores the cockles in her house. She pays the dealers \$3.80/basket and sells *A. tuberculosa* for \$4.14/basket and *A. similis* for \$1.72–\$2.07/basket. When the market is slow, she sells the cockles at her purchase price to pay the dealers. With the aid of a hired man, she takes the cockles in bags, which hold as many as two bushels, to markets in San Miguel and San Salvador on public buses. After she returns with the money, she pays the dealers for them.

Of the one of several small-scale cockle merchants in the coastal villages, the one in Huisquil, about 3 km north of La Union, buys cockles from her hus-

Figure 31.—Three El Salvador fishermen walk to a dealer to sell their bagged cockle harvests. They will purchase their daily food with the money they receive.

band and two other fishermen. During the day, she sells them at her stand in an open-air market in La Union, walking there and back with one or two of her six children who help to carry them.

Honduras

Honduras[16] has a cockle fishery in the Golfo de Fonseca (Fig. 33). Sections of the coastlines of El Salvador, Honduras, and Nicaragua border on the gulf, but about 80% of its shoreline is in Honduras. The principal areas for harvesting cockles are the mangrove swamps surrounding Bahia Chismuyo and those continuous with it to the south and west that border on the Bahia de La Union near the El Salvadorean border. Other less productive areas are the mangroves on the northwest side of Bahia de San Lorenzo and those on the east side of the Golfo de Fonseca in the Pueblo Nuevo-Cedeno area.

About 225 Honduran fishermen, besides nearly all the 300 fishermen from the La Union-Huisquil area in El Salvador, harvest cockles daily in the Honduras mangrove swamps. The fishermen live in various villages around the gulf, and as many as 30–50 Honduran fishermen live in each of the largest villages, such as Puerto Grande, Punta Raton, Puerto Nuevo, and Cedeno, and the coastal edge of the city of San Lorenzo (Fig. 34).

The regular fishermen harvest cockles 5–7 days a week, while some others harvest as few as 1–2 days a week. Their harvests usually are relatively small, 30–50 cockles/day, but some fishermen gather as many as 100/day. The harvests consist of *A. tuberculosa* and *A. similis*, but not *A. grandis*, which is now protected because it has become extremely scarce. Fishermen receive about $0.04/cockle except in March and April when they can get as much as $0.07/cockle. On most days, a typical fisherman earns from $1.00 to $1.50.

The cockle harvests were larger before Hurricane Mitch in 1998. Individual cockle harvests were 200–300/day and included some *A. grandis*.

Most fishermen go to the mangrove areas in canoes or pongos, but some go on foot. In addition, some beginners with no boats have had to swim across rivers as wide as 200 m to reach harvesting areas on the opposite side. If a small group, such as a family, does not own a canoe, which costs $100 new and can last 12 years, it pays about $10.00/month to rent one. Fishermen who go in a pongo usually travel with its owner who serves as a chauffeur. Some harvesters are barefoot, while others use low rubber boots, that are tied at their ankles; some use thin rubber gloves to protect their hands from cuts. To repel insects some fishermen wear long-sleeve shirts, and adult males often smoke cigars (which cost $0.17 each),

[16] Information for this section was obtained from 3 to 8 people in each village; the principal sources were Carlos Antonio Reina in Cedeno; Richard Alvarez, Santo Teodoro Alvarez, Carlos Ivan Cabrera, Luis Alberto Alvarez, Jose Manual Montoya, and Salvador Rodrguez Ortiz in Guapinol; Sonia Patricia Carcamo and Sulma Marisol Carcamo in Punta Raton; Jose Fuentes, Imperitris Fuentes, Natividad Vasques, and Felicita Flores Ziniga in Pueblo Nuevo; Maria Ernestrina Amador, Marlon Flores, Federico Pastrana, Romunda Posada, and Fausto Flores Sanchez in San Lorenzo; Maria Elsa Chirinos in Los Guatales; Jose Vaca in Los Langues; and Aureliano Avila, Maritzo Corales, Filomon Gonzales, and Rafael Rivas Gonzales in Puerto Grande. The principal sources in Huisquil, El Salvador were Thomas Contreras, Zapatos Garbales, and Maria Teofila Granados.

Figure 32.—An El Salvador cockle dealer counts the harvest into her bag while the fisherman counts with her.

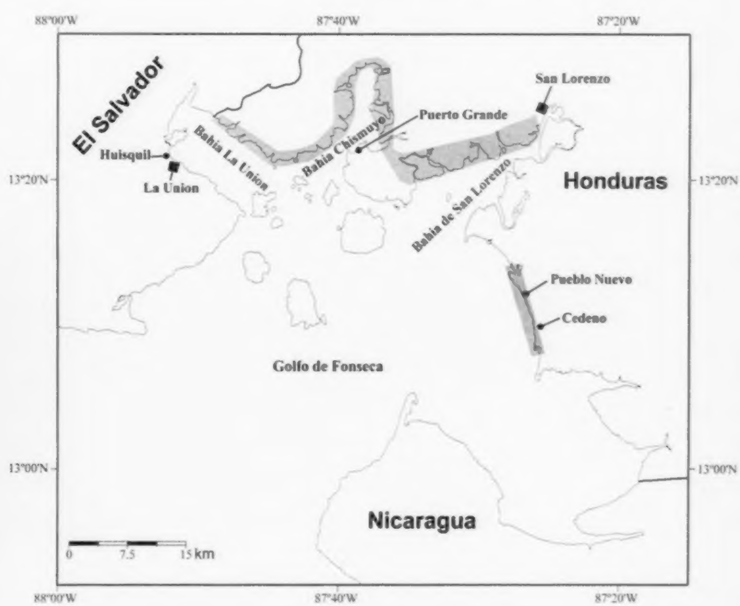

Figure 33.—Cockle harvesting areas in the Golfo De Fonseca coastline of Honduras and (partially) El Salvador and Nicaragua.

Figure 34.— A gathering of Honduran villagers answering questions about their lives. The author's interpreter (arrow) relays questions and answers.

while others burn bundles of small palm branches or dry cow and horse manure which is held in one hand while they harvest with the other.

As a consequence of Hurricane Mitch, some fishermen have found cockles so scarce in their local swamps that they move about in groups seeking more productive ones. One group of about 15 men, 16–35 years of age, from San Lorenzo had set up a camp in a field near Cedeno 30 km south of that city. They slept in hammocks hung between trees and in primitive huts they had built. They cooked their food by setting five rocks on the ground, setting fire to wood they placed on them, and holding a pan with food over it. A woman from the neighborhood set up a stove to cook tortillas which she sold to them. When the group had no food or money, they knocked mangoes out of trees, *Mangifera* sp., in the camping area to eat. Each man harvested cockles 3–4 days/week, going in groups in canoes to the mangrove swamps.

Hondurans do not eat many cockles, and they are displayed only sparingly by produce vendors on their street and market stands. Fishermen eat cockles once in a while. The cockles are sold to dealers, who take them on pickup trucks to market outlets mainly in Tegucigalpa, the capital, but many are sold in El Salvador. One buyer in Puerto Grande buys fish and shrimp for 6 months of the year and 750–1,000 cockles/day year-round. He delivers the fish and shrimp to a processing plant in Choluteca, 64 km away, every 2–3 days, and delivers the cockles in bags holding 400–500 to the central market in Tegucigalpa, 115 km away. He operates a small grocery store which occupies a room facing the street in his stucco house to enhance his income.

The main building of the huge central market in Tegucigalpa is divided into sections, with each section specializing in certain foods and other items. The tiny cockle section consists of four small restaurants, two on either side of a walkway. Each has 3–4 tables for serving customers and a bench placed alongside the walkway for holding 1–2 dishes of cockles, limes, and a couple of knives; all tables and benches in each are painted green. During June 2000, the restaurants purchased cockles from dealers for $48/1,000 ($0.048/cockle). They charged $1.70–$2.00/plate of 12–14 cockles on the half-shell (about $0.14/cockle), and each sold 20–30 such plates/day

Effects of Shrimp Farms

During the 1980's and 1990's, about 185 small and medium-sized shrimp farms and 38 large ones were established around the Golfo de Fonseca, mainly in its eastern half (Fig. 35). In 1999, the farms had 15,700 ha of ponds, and they produced 7,124 t of shrimp (Morales[17]).

The gulf has about 155,000 ha of mangrove swamps, of which the shrimp farms have developed 20,000 ha or about 13%. Of that, 2,000–3,000 ha were cockle habitat. Government officials had informed the local people that the demand for high priced shrimp in the United States was strong, and so some mangrove swamps had to be sacrificed to build shrimp ponds. In recent years, the shrimp farmers have been trying to protect the remaining mangroves in part by constructing their ponds on higher grounds on which different tree species grow (Mendosa[18]).

While construction of the shrimp farms has led to some habitat losses (and consequent fishing opportunities) for such commercial species as cockles and crabs, the farms have hired some local people to work for them. The farm workers are paid $3.78–$4.13/day; the legal minimum wage in Honduras is $3.44/day.

Environmental Support Groups

The Honduran government and a private company sponsor three agencies which have been active in protecting and enhancing mangrove swamps and cockles (preserve-the-environment awareness is prevalent in Central America). One is Promangle, a government office, established in 1998 to promote mangrove conservation and management in the Golfo de Fonseca to counter the environmental devastation caused by Hurricane Mitch, which also destroyed many villagers' homes. Since "Mitch," the villagers have cut down some mangrove trees to be used for house construction and fuel. Promangle has encouraged people to use other types of wood, and has planted other tree species which can be used for wood. In 2000, Promangle, with assistance from villagers, replanted 150–160 ha of mangroves (Mendosa[18]).

[17] Morales, Luis, Honduras Oficina de La Pesca, Tegucigalpa, Honduras.

[18] Mendosa, Carlos V., Agronomy Engineer, Promangle, Honduras.

Another Federal agency is Progolfo, while "CODDEFFAGOLF" (Comite para la Defensa y Desarrollo de la Flora y Fauna del Golfo de Fonseca [Committee for the Protection and Development of the Flora and Fauna of the Gulf of Fonseca]) is a private agency. The goals of the three agencies somewhat overlap, and among them they attempt to 1) teach the fishermen to protect the mangroves, 2) work with the shrimp farms to achieve the least environmental damage, 3) help the fishermen write proposals to groups offering development money, and 4) recommend new government laws and rules to improve the finfish and cockle economies.

Nicaragua

Fishermen in Nicaragua[19] harvest *A. tuberculosa* and *A. similis* in Estero Real which faces the Golfo de Fonseca, and in about six small estuaries along the Pacific coast (Fig. 36). About 160 fishermen harvest cockles daily in the country: 30 in Estero Real, 60 in Estero Padre Ramos, 30 in Bahia de Corinto, 10 in Puerto Sandino, and perhaps 30 in all remaining estuaries combined. Each fisherman harvests 120–475 cockles/day. They usually walk them to a dealer's house who then sends them on pickup trucks to markets in towns and cities, such as Managua, the capital. The dealers pay US$0.36–$0.39/dozen ($0.030–$0.033/cockle) for them. The cockles are sold in central markets, along city streets, in many small roadside eating stands, and also in city restaurants, which use them in seviche. One restaurant sold seviches with 6 cockle meats for $1.95, while another more upscale restaurant in a hotel sold seviches with 12 cockle meats for $4.50.

Costa Rica

The principal *A. tuberculosa* and *A. similis* harvesting areas in Costa Rica[20]

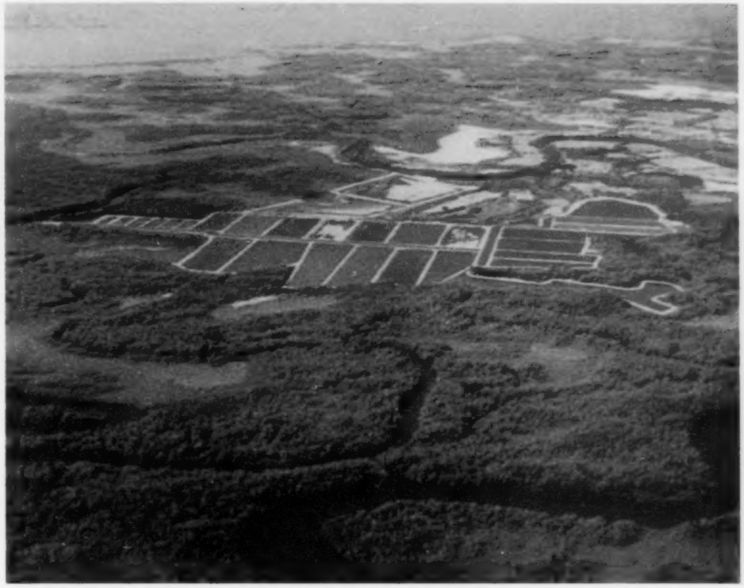

Figure 35.—A shrimp farm (middle) and mangrove swamps and canals (foreground) in Ecuador.

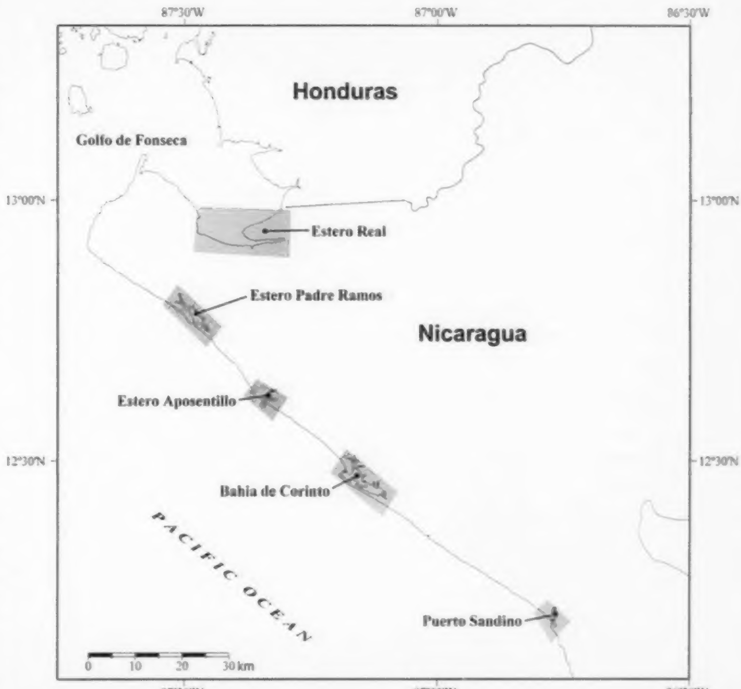

Figure 36.—Pacific coast cockle harvesting areas of Nicaragua.

[19] This section was condensed from a previous paper by MacKenzie (1997).

[20] Information for this section was obtained from interviews of 3–8 people in each village; the principal sources were Dr. Jose A. Vargas Z, University De Costa Rica, San Jose; Navidad Urena Moraga in Chomas; Jaime Gonzales in Palmar Norte; Rodrigo Benavidez in Ciudad Cortez; Jose Antonio Araya Abarca in the Sierpe area; Francisco Chavez Mariano Barquero and Elias Rodriquez in Golfito; and Huber Gonzalez, Incopesca Office in Golfito.

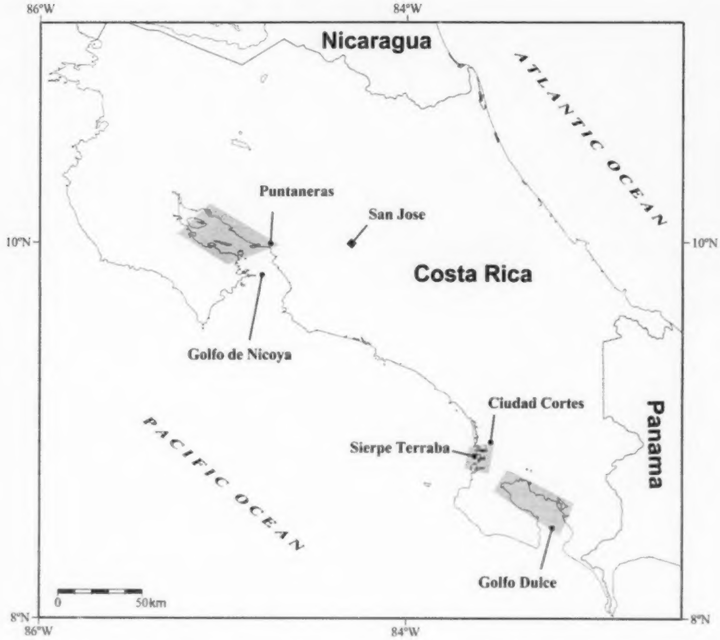

Figure 37.—Cockle harvesting areas in Costa Rica.

are the Golfo de Nicoya, Sierpe-Terraba, and Golfo Dulce (Fig. 37). About 200 fishermen harvest cockles around the Golfo de Nicoya, and 300 harvest them in Sierpe-Terraba and Golfo Dulce combined, for a total of about 500 cockle fishermen in the country. The fishermen's children harvest cockles whenever schools are not in session, and they eventually leave school and harvest cockles full time, with their parents, when they are 10–13 years old. Each fisherman harvests from 145 to 500 cockles/day, while each family of 3–5 members harvests about 700 cockles/day. Dealers pay $0.29–$0.38/dozen cockles ($0.024–$0.032/cockle).

About 15 families and some individuals, totaling 30–40 people, harvest cockles in the village of Chomes, just north of Puntarenas on the northeast side of the Golfo de Nicoya. Each fisherman harvests 200–350 cockles/day. One, a housewife, harvests cockles by herself 7 days/week. She walks to the shore, paddles her canoe to a harvesting site, and collects the cockles in a plastic bucket (Fig. 38). Later, at home she puts them in an onion sack on the days she is going to sell them. Each week, she sells the cockles she collected in 4 days and retains those taken the other 3 days to prepare for her family (which includes her husband and four children) to eat at home. The cockles are eaten for lunch and dinner and are prepared three ways: 1) boiled with rice, 2) in seviche, and 3) in soup. For variety, her family also eats finfish and chicken with the staple rice. A dealer comes to her house in a pickup truck to purchase her cockles on Wednesdays and Saturdays, paying her $4.00/100 cockles ($0.04/cockle). Market demand is strongest from November through April, the dry season.

Some fishermen live long distances from good cockle areas and must travel and camp out for a few days while harvesting. One fisherman in the small community of Purrujas near Golfito does this 3–4 times a month with 1–2 of his sons. They travel to good sites in their motor-powered canoe, live in a primitive camp on high ground near the mangrove swamps, and gather cockles daily during low tides. They remain there for 4 days each time subsisting on rice, beans, and spaghetti, with each person harvesting 200–250 cockles/day. They keep the cockles fresh by holding them in net bags set in the mud in the mangroves where the water can cover them during high tides. A small quantity is set aside to eat at home, and a dealer comes to their house weekly to purchase the remainder, paying $0.36/dozen cockles ($0.03/cockle).

Some Costa Rican dealers shuck the cockles, selling the meats and giving the blood separately to restaurants and fish markets sparing them that task. As mentioned, the dealers in most other countries sell whole cockles. One dealer in Ciudad Cortez opens cockles in a shed located on a high bank off the Grande de Terraba River. He has a marble-topped table about 3 m long and 2 m wide. He and his helper each use a "knife," about 7 cm wide and 5 cm high, that is fastened to wooden block on the edge of the table. They put the edge of each cockle on the knife, hit them with a wooden hammer to open them, and then remove their meat with their fingers and put them in a bucket with ice. The cockles' blood runs down the sides of the knives, then into a groove in the table top, and finally collects in a bucket on the floor. The shells are discarded down the bank. The meats are counted into plastic bags, either 100 or 500 meats/bag (Fig. 39), and the blood is poured into plastic bags, about 500 ml/bag. Both are placed in a refrigerator. The meats and blood are taken about 200 km to San Jose, the capital, in a cooler on a pickup truck.

In Costa Rica, about 90% of the cockle meats are served in seviche, with the rest as whole meats boiled with rice. The selling price for a seviche with cockle meat is $2.00–$3.60, depending on its size (a large seviche has about 30 meats mixed with an equal volume of condiments). The selling price of cockle meats with rice is $2.40 for a medium portion and $3.60 for a large portion (about 2 large cups of rice and 12 cockle meats). Cockle blood can be added to seviche with the meats, onions, and spices, or drunk as seviche juice. Served in small glasses, seviche juice is sold in bars for $0.50 a glass to be drunk with beer. It consists of cockle blood, lime

Figure 38.—The hands of a female Costa Rican cockle harvester who probes in the mud only with her right hand, scarred from the activity.

Figure 39.—Bags of blood (L) and meats (R) of *Anadara tuberculosa* ready for transport to San Jose, Costa Rica.

juice, onion, chile peppers, and tabasco sauce. Male bar patrons believe the juice increases their virility.

Panama

The principal *A. tuberculosa* and *A. similis* harvesting areas in Panama[21] are between the border with Costa Rica and the Peninsula de Azuero (Fig. 40). About 220 cockle fishermen harvest daily in the country: 125 in Bahia de Muertos and Boca San Pedro in the David area, 6 in the Santa Cruz area, 10 in the Guabala area, 20 in the Golfo de Montijo, 12 in Mensabe port, and 20 in Bahia de Charme. Each fisherman in the David area gathers 180–240 cockles/day, while in other areas, less-intensely harvested, about 480–600/day are taken. Dealers pay \$0.20–\$0.25/dozen (\$0.017–\$0.02/cockle) for them.

One dealer in the David area sells cockle meats and has the cockles shucked by a team of three. Harvesters from Isla Savilla and Isla Mono bring their cockles to him in net bags, 50 dozen/bag. When 4 such fishermen delivered 10 such bags to this dealer, the first shucker lowered the bags, one at a time, into a tub of boiling water for a couple of minutes to kill the cockles and make them easy to open and then lifted them onto a table (Fig. 41). The second person, standing beside the table, opened the cockles using a hatchet (Fig. 42), and the third person standing alongside removed their meats with his fingers and put them in a large bowl. The 10 bags were processed in 2.5 h. The meats were packaged in 1 lb bags, chilled, and then delivered to markets. One market, two blocks away, purchased about 25 bags of meats a week from the dealer for \$1.25–\$1.75/bag and resold them for \$2.00 each. A large store in Santiago retailed cockle meats for \$2.50–\$2.75/pound.

In Panama, cockles are eaten in 1) seviche; 2) a dish with tomato sauce and garlic; 3) soup; and 4) dishes called wacho (rice, beans, tomato, and cockle meat with spices) and sancocho (corn, potatoes, onions, and cockle meats, but usually chicken). In restaurants, a small seviche with five cockle meats sells for \$1.50–\$1.75, while a regular-sized seviche sells for \$2.50–\$3.00.

Anadara grandis *in Panama*

Fishermen harvest *A. grandis* to a small extent in Panama including in the Archipielago de las Perlas (MacKenzie, 1999). Its local name is cocaleca, and children remove them from muddy-sand areas during extremely low tides for consumption at home.

[21] Information for this section was obtained from interviews of 3–8 people in each village; the principal sources were Jose Valerde and Wilfredo Pinto in Charme; Eustorgio and Emelida Florez in the Golfo de Montijo area; Victoriana Rodriguez in Quebala; Maria Isabel Carrillo, Obidio Domingoes Concepcion, Yajarra Valdez, and Alvin Vega in Chirique; Ladislao Montenegro in the Santa Cruz area; Rufina Montenegro, and Hugo and Isabel Marisqueria in the David area.

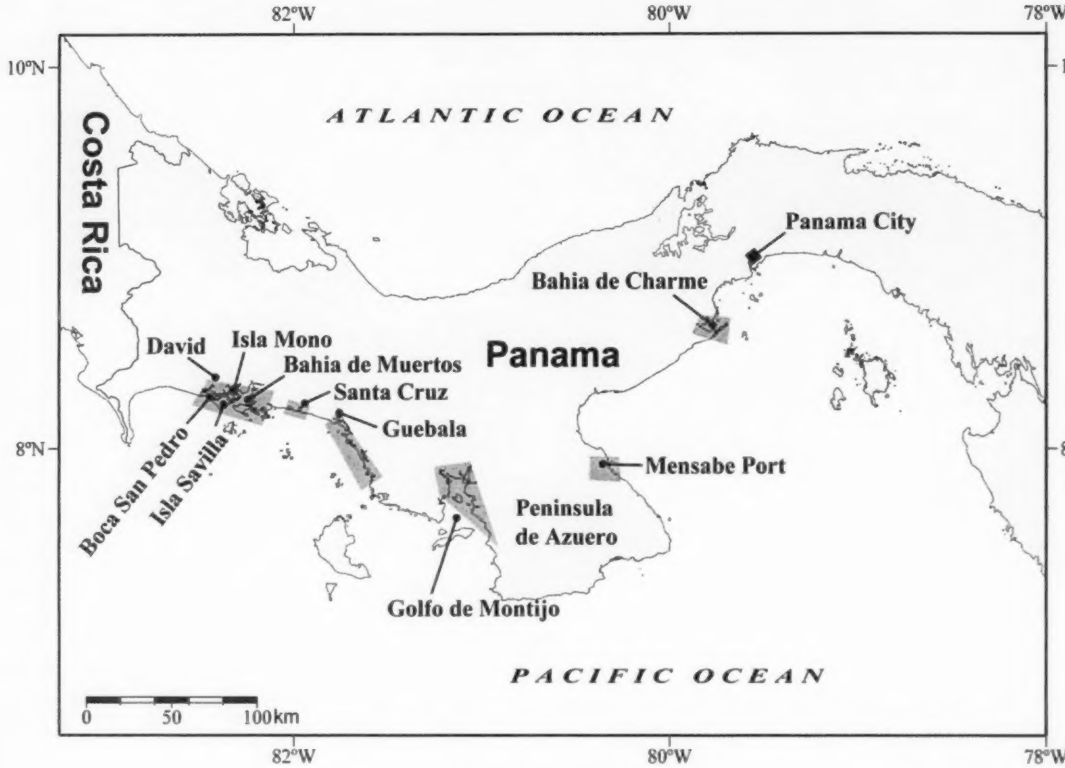

Figure 40.—Cockle harvesting areas in Panama.

Colombia

Colombia[22] may have more cockle fishermen than any country except Ecuador, but a country-wide census of them has yet to be made. Cockles occur in mangrove swamps from Cabo Corrientes to the border with Ecuador (Fig. 43). In Tumaco and Mosquera, 2 towns in the southernmost mangrove area, about 800 families, with 4–5 people in each for a total of nearly 4,000 people, are engaged in the fishery. The fishermen are mainly women and children who paddle to the harvesting areas in canoes. They harvest throughout the year, but the demand is strongest in December and during Semana Santa, the week before Easter in April (Ardila and Cantera, 1988). Each family harvests 4–5 days a week (Ardila and Cantera, 1988) and about 23 days a month (Plaza[11]). The average daily harvest is about 215 cockles/person, but ranges from 50 to 350 cockles/person (Plaza[11]). Cockles are an important food for the coastal people and a common species in markets. Any excess cockle harvest is held in small palm-frond houses ("piangua houses") set in the mud in intertidal areas (Squires et al., 1975). The number of cockle fishermen from Cabo Corrientes to the city of Buenaventura, a distance of about 200 km, has not been censused (Plaza[11]).

Squires et al. (1975) said that in 1971, about 36 t of cockles (20,000 cockles/t) were recorded in markets in the port city of Buenaventura, and an additional 36 t were shipped from Buenaventura to inland towns and the city of Cali. At Tumaco, 44 t were exported to Ecuador and almost as many were estimated to have been sold to residents in and around Thymic, Colombia. The total marketed was at least 150 t, and a similar quantity may have been eaten by the coastal villagers. The total 1971 harvest was estimated at 300 t (6 million cockles). Artila and Cantera (1988) said that local people prepare cockles for eating as they do in other countries, i.e. in seviche and as cooked meats in rice or soup. They also said *A. tuberculosa* is the species shipped to Ecuadorean markets. *A. similis* does not live long enough.

In describing the poverty of the Colombian fishermen, Plaza[11] said that some relief would follow if they could be provided with outboard motors for their canoes. This would enable many to harvest in more remote areas where cockle stocks are relatively large, thereby increasing harvests for everyone.

[22] The information for this section was obtained from papers by Squires et al. (1975) and Ardila and Cantera (1988), and a telephone interview with O. Gustavo Plaza who is with Alcaldia Municipal de Tumaco, Colombia, in January, 2000.

Ecuador

Ecuador[23] has the largest number of cockle fishermen, estimated at 5,055, in Latin America (except perhaps Colombia). About 4,000 fishermen harvest in the Esmeraldas Archipelago area near the Colombian border, 130 in the Muisne-Canaveral area, 35 in the Sabana Grande-El Moro area, 90 on Isla Puna, and 800 in the Archipielago de Jambeli close to Peru (Fig. 44). As elsewhere, *A. tuberculosa* exceeds *A. similis* in landings: A late 1990's survey by Santos et al. (1998) found the percentage of *A. tuberculosa* landed was 92 in El Moro, 80 in Puerto Bolivar, and 55 in Puerto Jeli. In recent years, the unrestricted entry of people into this fishery has generated great pressure on Ecuador's cockle resources (Rosero and Burgos, 1999).

The prices paid for cockles are strongly influenced by transportation costs from the harvesting areas to the principal markets of Guayaquil and Quito, the capital (Santos and Villon, 1998). In 1999, for example, the cockle fishermen in the Archipielago de Jambeli area, located just 180 km from Guayaquil, were paid 3–5 times more for cockles than the harvesters in the Esmeraldas Archipelago, the most distant location from the main markets. Transportation from the Esmeraldas Archipelago requires an 80 km boat trip to the city of Esmeraldas, then a transfer to trucks, followed by an overland drive of 375 km to Guayaquil.

The Esmeraldas Archipelago area is comprised of an island group and mainland shores with many creeks and canals, all at least partially lined with mangrove swamps. Some swamps have been de-

[23] Information for this section was obtained from interviews of 5–10 people in each village; the principal sources were Pedro Apolinario, Antonio Arroyo, and Nircharror Garcia in Puerto Sabana Grande; Juan Garcia Georgie Lino in Puerto Morro; Filipe Medina, Euro Castro, Mauro Cruz, Pluto Torrez, and Andre Sanchez in Isla Puna; Herminizo Madrid, Uberliza Bustos, Estela Luque, Enrique Ford, and Ludy Garafalo Monte on El Balito Island; Maritza Segura on Tambillo Island; Ramon Arteaga and Oscar Regifo in Canaveral; David Cruz, Euprene Cruz, Fabricio Escobar, Nicolas Espinosa, Juan Fernando Jaramillo, Maximo Vivero in Puerto Bolivar; Francisco Solano, and Nemesio Soriano in Puerto Jeli; and Florentino Mayon and Manual Pelaez in Puerto Huattaco.

Figure 41.—Hot-dipping cockles (L) and shucking them (far R) in Panama.

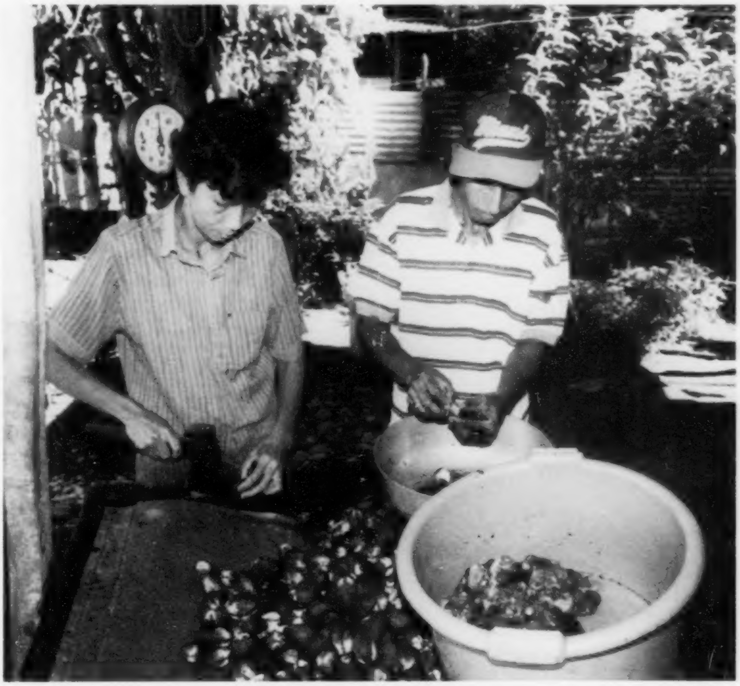

Figure 42.—Opening cockles with a hatchet (L) and removing the meats (R) after they were hot dipped in Panama.

stroyed to construct shrimp farms, but the area is an environmental reserve and so the government has tried to halt any further spread of shrimp farms. The mangrove swamps constitute about 16,400 hectares (Santos and Villon, 1998).

The cockle fishermen, who range in age from 7 into the 50's, live in villages on the islands and the mainland. Most are women and children; while some men harvest cockles, most catch finfish and shrimp, or seed shrimp (juveniles) for the shrimp farms. The fishermen harvest cockles year-round, 6 days a week, but not on Sundays. They use canoes with paddles and pongos with motors of 8–40 hp to reach the harvesting areas. If fishermen do not own a boat, they pay boat owners 25 cockles or an equivalent amount in money to chauffeur them to and from the harvesting areas (Santos and Villon, 1998).

Many fishermen wear gloves on their hands and carry a bundle of burning coconut leaves in one hand to repel insects while harvesting with the other. Each harvests 100–300 cockles/day. They keep some small *A. tuberculosa* and some *A. similis* to eat at home in seviche and soup, and sell the rest to dealers in the villages.

Each Esmeraldas dealer buys cockles from 10 to 20 fishermen, paying \$1.05–\$1.25/100 *A. tuberculosa* (\$0.01–\$0.013/cockle) and selling them for \$1.25–\$1.50/100 (\$0.013–\$0.015/cockle). Dealers pay \$0.50–\$0.75/100 *A. similis* (\$0.005–\$0.008/cockle). Each fisherman usually averages slightly over \$3.00 a day in sales. Dealers ship the cockles mainly to Guayaquil and Quito via the city of Esmeraldas. Large cockle imports from Colombia through the city of Esmeraldas compete with Ecuadorean cockles and reduce their prices in the main markets. The principal market for imported Colombian cockles is Guayaquil (Santos and Villon, 1998).

The Canaveral area, 90 km southwest of the city of Esmeraldas, has about 50 cockle fishermen, who harvest 6 days a week, each gathering 100–150 cockles/day. Dealers pay them about \$1.55/100 cockles (\$0.016/cockle).

Puna Island, 50 km long and 25 km in breadth, lies near the center of the Golfo de Guayaquil and is 45 km due south of Guayaquil. A large 17 × 17 km mangrove swamp, with at least four islands and several canals, is situated near the center of its east side. Campo Alegre is the largest village on the island, and about 80% of its workers, all males aged 8–70, harvest cockles in the swamp. They go about 20 days/month, year-round, and each usually takes 125–250 cockles/day. The dealers pay them about \$1.90/100 cockles (\$0.019/cockle), so they earn \$2.50–\$4.40/day. The dealers pay \$0.65/bag (3,000–4,000 cockles) to have the cockles trucked from the village several km over an unpaved road to a shore location and an additional \$0.65/bag to have a fiberglass boat take them to the mainland port of Posorja. From there, the cockles are trucked 130 km to Guayaquil for sale, mainly at the fish market in Mercado Sur.

The group of islands called the Archipielego de Jambeli, 40 × 10 km in length and breadth, lies next to the shore on the

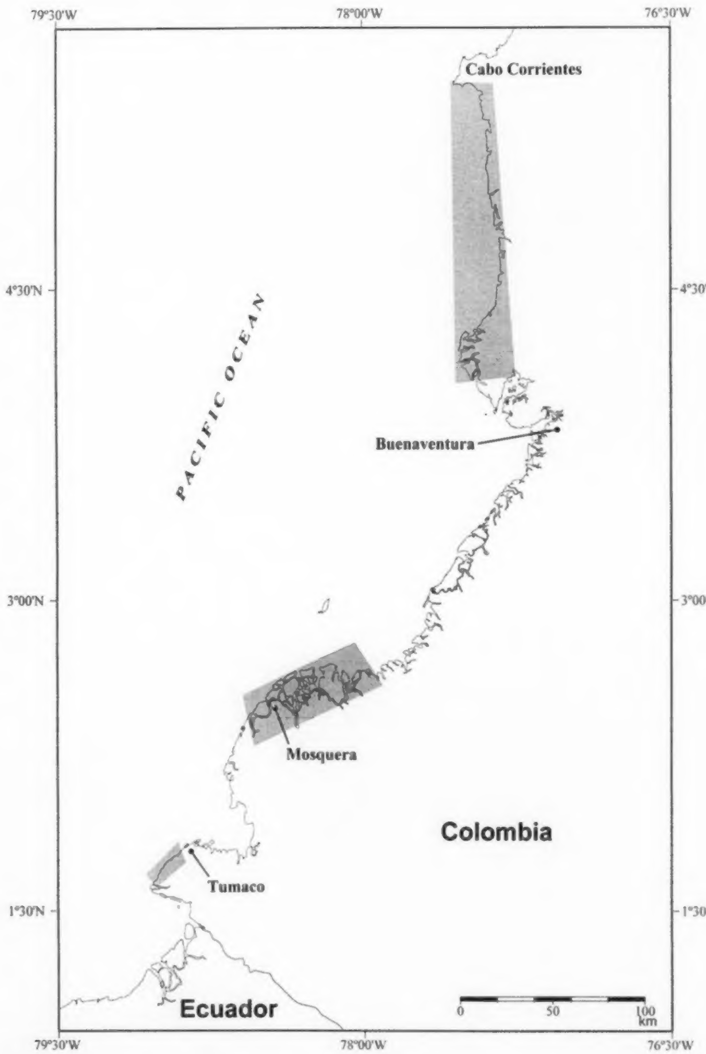

Figure 43.—A section of Colombia's Pacific coast showing cockle harvesting areas.

lower east side of the Golfo de Guayaquil. Lining the shores of the islands and many long canals are mangrove swamps with cockles. At least 7 villages on the islands are supported largely by cockle harvesting. Nearly 500 cockle fishermen, children included, reside on the archipelago, and at least 300 additional adult cockle harvesters travel there daily from 3 mainland ports, Puerto Bolivar, Puerto Jeli, and Puerto Hualtaco, which face the archipelago. Many of the 300 additional harvesters (Fig. 45) are migrants whose former harvesting areas to the north were destroyed during the 1980's and 1990's by shrimp farm construction (Altamirano et al., 1998). Other fisheries take crabs with traps, demersal finfish (covina, bagre, and pompano), and large pelagic finfish throughout the year (Santos and Villon, 1998).

Cockle and crab fishermen, nearly all adult males, from the mainland ports ride to the harvesting areas on 7.3-m fiberglass boats propelled by outboard motors; each boat carries as many as 22 harvesters to and from the harvesting areas. Some go to the archipelago and camp for 2–4 days while harvesting. Cockle harvests there also continue year-round, 6 days a week.

The usual daily harvest is about 200 *A. tuberculosa* and *A. similis*/fisherman. About 20 dealers each purchase between 2,000 and 20,000 cockles daily (Altamirano et al., 1998), paying \$3.50–\$5.00/100 *A. tuberculosa* (\$0.035–\$0.05/cockle). Most cockles are sold in Guayaquil while some go to Quito, and others go to the nearby city of Machala and other nearby population centers, i.e. Pasaja, Santa Rosa, Arenillas, and Huaquillas.

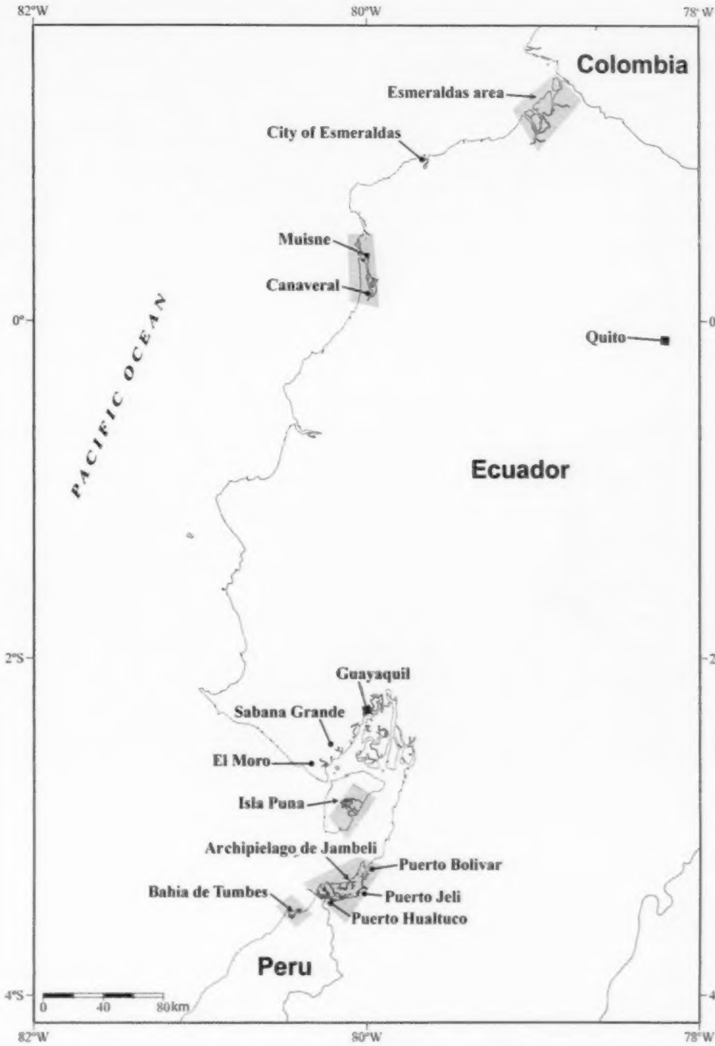

Figure 44.—Cockle harvesting areas in Ecuador and northern Peru.

Anadara grandis *in Ecuador*

Small quantities of *A. grandis* are harvested in Ecuador. The fishermen are paid about \$0.16 each for them, and they are sold alongside *A. tuberculosa* and *A. similis* in roadside markets and the fish market in Mercado Sur in Guayaquil.

Southern Ecuadorean Markets

The fish market in Guayaquil is part of a large market called Mercado Sur located near the city's waterfront. Trucks deliver finfish, shrimp, cockles, and crabs from dealers in various Ecuadorean villages and ports to merchants at around 3 a.m. every morning except on Sundays. Some cockles also come in from Colombia and Peru. The merchants' produce stands line both sides of the main street, and some are within nearby buildings (Fig. 46). Cockles are sold within an area of about 1.5 blocks. Each of the larger merchants purchases bags of 3,000–4,000 cockles for \$60 (about \$0.016/cockle). During the day, they remain by their stands to serve customers (Fig. 47 a,b), charging about \$0.062/25 cockles (\$0.025 each) for most cockles but \$0.05 each for the largest.

Individual merchants usually sell from 1,500 to 2,000 *A. tuberculosa* and *A. similis*/day during the week, but their sales increase to about 3,000 cockles on Saturdays because Ecuadoreans have a tradition of eating seviche, many made with cockles, every Saturday. A few of the smallest merchants at the edges of the main area each sell about 500

cockles/day, earning $1.25, or enough to largely pay for their meals. The cockles remain alive for 3–4 days in the market.

Shrimp Farm Effects in Ecuador

Shrimp farming developed in Ecuador mostly during the 1980's and 1990's and is far more extensive there than in any other country of the Americas. According to Rosero[2], about 178,000 ha of coastal areas in Ecuador now are covered with shrimp ponds: About 49,000 ha were once pristine mangroves (27.5%), 83,000 ha (46.4%) were constructed on high ground, and 46,000 ha (26.1%) were constructed where salt beaches existed (Fig. 48). The ponds range from 10 to 20 ha in area and, in mangrove areas, were constructed after first removing large areas of mangrove swamps while leaving intact the mangrove fringes along the estuarine edges to protect the ponds from storm surges. Bravo and Abarca[24] said about 50% of the shrimp farms located in the mangrove swamps had harbored cockles.

[24] Bravo, M., and N. Abarca. Undated. Potential of concha prieta (*Anadara tuberculosa*) in polyculture with white shrimp (*Panaeus varmamei*). Unpublished manuscript.

Figure 45.—Fishermen carry their cockle harvests ashore in Puerto Bolivar, Ecuador.

Figure 46.—Ecuadorean merchants selling cockles on a city sidewalk.

The shores of the Golfo de Guayaquil have 60% of the shrimp farms and are the principal shrimp-producing areas. About 36,600 ha of its mangroves (67.7% of the total) have been removed and replaced by the shrimp farms. The farms average at least 100 ha, but some exceed 500 ha. The northern provinces of Esmeraldas and Manabi have 9% of the farmed area, the farms there being mostly under 50 ha. Many farms rely on wild seed shrimp for stocking ponds, but most use hatchery seed at least during the summer (Griffith and Swartz, 1999).

In 1996, Ecuadorean shrimp yields were 700 kg/ha, and total production of farmed shrimp was about 110,000 t (Griffith and Swartz, 1999). Such shrimp yields compare roughly with a standing crop of 1,200 kg/ha of cockle meats. This is a maximum figure for cockle meats and is based on Baquiero's Mexican data (10 market-sized cockles/m^2 are present; 100,000/ha are present; they weigh 8,000 kg, and their meats weigh 1,200 kg [about 15% of whole weight is meat weight]). However, while all the shrimp in the farms are harvested, probably far less than half of the market-sized cockles are taken from their habitats in a year even under heavy harvests.

Removal of the mangrove swamps and construction of the shrimp ponds and canals have led to some fishery, social, and environmental changes. The cockle fishermen's harvesting has been concentrated into smaller areas because less swamp area is available, and many fishermen have had to travel longer distances to reach good harvesting areas. The consequences have been smaller harvests for fishermen, some of whom have had to emigrate from their villages to other harvesting areas or try to find other means of earning money. For example, in 1993, a fisherman in Muisne could harvest about 400 cockles/day, but by 1997 his harvest was 120 cockles/day (Rosero and Burgos, 1998).

The fishermen's movement to other areas has placed pressure on the cockle stocks in those areas. The potential danger is that if the harvesting pressure

Figure 47a—A sidewalk stand displays cockles for sale in Ecuador.

Figure 47b.—Frontal view of Ecuadorean cockle stand. *A. grandis* is in lowest tubs and *A. tuberculosa* and *A. similis* are in uppermost tubs.

Figure 48.—An Ecuadorean shrimp pond (background) and its feed canal (foreground).

increases, the fishermen may take increasingly smaller and immature cockles and ultimately deplete the stocks (Santos and Villon, 1998).

Some fishermen who have remained in the villages where shrimp farms are extensive have had conflicts with the farmers (Santos and Villon, 1998). If fishermen harvest near the shrimp ponds, the farmers usually drive them away or confiscate their boats, collecting bags, and cockles. The villagers

have also lost their wood supply which they had used for dwelling construction and cooking their food.

The environmental problems include: 1) loss of wildlife including estuarine life (i.e. birds, finfish, cockles, and crabs), 2) alteration of water flow in the mangrove zones, which has reduced the growth and development of the mangroves, 3) increased quantity of sediments in the water due to channeling of the water from the estuaries to the ponds, and 4) damage to the central mangrove areas from the action of storms due to the loss of protection (Boyd and Clay, 1998).

In addition, Turner (2000) reported that yields of wild shrimp declined in Ecuador (as well as in Thailand and Vietnam) when shrimp ponds were built in the mangrove zones. He explained that a strong, positive relationship exists between shrimp productivity and the areal extent of estuarine vegetation present in wetlands. In regions where substantial losses of wetlands occur, shrimp losses follow immediately.

While shrimp farming was developing in the mangrove swamps during the 1980's and early 1990's, government agencies provided little or no oversight or regulation. But during the 1990's, a government agency, Programa de Manejo Recursos Costeros (Program of Coastal Resources Management), has become involved and has attempted to: 1) strengthen the ability of the government to deal with the interactions of groups that want to use the mangrove swamps, 2) reduce conflicts between shrimp farmers and cockle and crab fishermen, 3) plan the construction sites of new shrimp farms in a way to minimize losses of mangrove swamps, and 4) restore mangrove swamps where the shrimp farmers have abandoned ponds. The agency's goal is to sustain the swamps as much as possible, so as not to diminish the livelihoods and qualities of life of future generations of coastal villagers (Altamirano et al., 1998; Anonymous, 1999a,b).

In 1996, a group named the Unidad de Conservation Y Vigiliancia de Puerto Bolivar (Unit of Conservation and Vigilance of Puerto Bolivar) gave custody of 120 ha of mangrove swamps in the Archipielago de Jambeli to a local association of fishermen and local residents. The objectives have been to maintain the mangroves and increase the cockle population of the area. By 1998, the group had planted mangrove seedlings in 14 ha and established 4 plots of 276 m^2 each to be used for planting cockle seed (Altamirano et al., 1998).

The government has regulations in place that prohibit further destruction of the mangroves, but local residents fear that more shrimp farms will be constructed in the future. The fishermen and other villagers have wanted someone to look out for their interests, because in the 1980's and early 1990's such outside support was absent.

Peru

Bahia de Tumbes, located in northern Peru[25] about 20 km south of the Ecuadorean border, is the southernmost extent of the mangrove cockles' range (Fig. 44). Two fishing villages border on the bay. One, Puerto Pizzaro, has about 40 cockle fishermen (men, women, and children) who range in age from about 9 to 60. The men divide their time about equally between harvesting cockles and netting finfish. The fishermen usually harvest cockles in family groups, which paddle to the harvesting areas in dugout canoes 6 days/week. Each fisherman collects about 100 cockles/day. The other village is Bendito which has about 35 cockle fishermen, all adult males, each harvesting 75–100 cockles/day. The fishermen's families eat some of their small cockles in seviche or as boiled meats with rice.

Two dealers live in the villages and drive pickup trucks to the fishermen's homes to collect the cockles, paying about $3.40/100($0.34/cockle) for them. When they distinguish between *A. tuberculosa* and *A. similis,* the latter brings half as much money. They take nearly all the cockles about 1,100 km southward to Lima, the capital, for sale, with the remainder going 300 km northward to Guayaquil, Ecuador.

From 60% to 70% of the mangrove-cockle areas in the Bahia de Tumbes have been removed for construction of shrimp farms, and the cockle resource has been reduced by that much, according to the villagers. Some people net seed shrimp along the shoals of the bay for sale to the farms.

[25] Information for this section was obtained from interviews of 3–8 people in each village; the principal sources were Eminiano Medina and Jose Oyola, Puerto Pizzaro.

Suggested Research

A plethora of studies could be made of the three cockle species. Especially lacking is information concerning cockle ecology. The most important research for obtaining information to manage them efficiently for commercial exploitation are:

1) An analysis of the likely predation that occurs on juvenile *A. tuberculosa*, *A. similis*, and *A. grandis* by some of their faunal associates, i.e. finfishes, shrimps, hermit crabs, and gastropods. Such studies might suggest a means of reducing predation so that stocks of cockles could be increased, thereby improving the welfare of the fishing communities. Since alphaeid snapping shrimps are predators of juvenile quahogs, *Mercenaria mercenaria*, in North Carolina, U.S.A. (Beal, 1983), the alphaeid snapping shrimps in the Latin American mangrove swamps might be predators of juvenile mangrove cockles.
2) Ecological interactions between the mangrove trees and the cockles.
3) Distribution of *A. grandis* in subtidal areas.
4) Sizes of spawning *A. tuberculosa* and *A. similis* stocks in mangrove swamp areas that are impenetrable by fishermen.

Suggested Management

The cockles in all countries, except Mexico, are under heavy harvesting pressure, in part because cockle harvesting is the only remunerative work available to many villagers. Thus far, cockle stocks are not being depleted because cockles are harvested at sizes at which they have already spawned, stocks of mature cockles everywhere lie within dense mangrove stands which are difficult or impossible for fishermen to reach, and the hand harvesting does not kill

juveniles or adversely affect the cockle habitat. Juvenile recruitment continues.

The laws specifying minimum sizes of cockles to be harvested protect the spawning potential of the cockles. They need to be implemented if fishermen numbers increase in the future and begin to harvest immature cockles along with adults. This potential looms because the fishermen have relatively large numbers of children surviving to ages at which they can help in the harvest. But any efforts to reduce the take of mature cockles, to prevent overharvesting could deepen the poverty in the fishing communities, and they probably will not elicit an increase in cockle recruitment. Instead, programs to conserve and improve the cockle habitats may be the most fruitful actions to take. Numerous papers describe how oyster abundance has been enhanced in North America and Europe by habitat improvement, i.e. spreading shells and predator control. Many examples are listed by Dugas et al., 1997; Ford, 1997; Goulletquer and Heral, 1997; Jenkins et al., 1997; MacKenzie, 1997a,b; and MacKenzie and Wakida-Kusunoki, 1997.

Preserving the mangrove swamps intact, increasing their sizes, and reducing predation on the cockles are sound conservation and enhancement actions. Planting mangrove seeds and transplanting mangrove seedlings to suitable areas might increase the size of the swamps. Fishes that prey on juvenile cockles might be seined regularly along the edges of swamps before the tidal rise allows them to swim into the mangrove swamps to search for food, and perhaps ways could be found to reduce the destruction of juvenile cockles by crustaceans and gastropods. Pointing out to urban consumers the health benefits of eating fish and cockles might also increase prices for the fishermen, as has occurred in the United States.

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Appendix

I collected most of the information for this paper by driving an automobile or pickup truck to fishing villages, making observations, and then interviewing as many cockle fishermen, fishermen's wives, and dealers in each village as possible and making a photographic record. I am not fluent in Spanish, and so a hired interpreter, in most cases a college student from the country being surveyed, acompanied me. The interpreters contributed information about the culture and economies of their countries and directed me to the villages. When we stopped in a village and began to ask 2 or 3 people questions, a crowd of 4–15 adults of both sexes and mixed ages and their children commonly gathered around us (Fig. 34). I asked the adults the series of questions listed below and recorded the answers in a notebook. Two to three people from the groups answered most of the questions, but I consistently sought and received further information from others. In addition, many fishermen who lived in isolated homes were asked the same questions individually. The interviews lasted 20–100 minutes each.

Listed below are two sets of questions and topics that were prepared before I visited the countries. The first set is a list I asked villagers in every country. The second set was used to obtain more information about the physical, economic, and cultural setting of the cockle fisheries. People in Honduras and El Salvador were interviewed for this topic. I asked the questions in about all villages, large and small, where cockle fishermen lived and in several isolated homes in Honduras. The same questions were asked of several villagers in Huisquil, El Salvador. Most interviewees were women. Obviously pleased that an outsider was showing an interest in their lives, they answered nearly all questions freely and without inhibitions, but they were sensitive about those relating to food and child care. Obtaining sufficient food for each meal was a consistent struggle for the villagers, and I did not always trust the answers I was getting about food: Some people seemed to be exaggerating the quantity and quality of the foods eaten. I found the best way to obtain information I could trust was to ask individuals what they had eaten their previous meal. For example, when I asked a man, 50 years old, about this with his family present, he said they ate eggs and cereal for their breakfasts, but later when I asked his son, about 14 years old, privately what he had had for breakfast, he said 2 pieces of bread and a cup of coffee. I believed the son. Women complained that their husbands spent little time helping them care for their children, and some wives had been abandoned by their husbands. The information is presented in the section "Human Life in the Cockle Fishing Villages."

I showed a draft copy of the section, "Human Life in the Cockle Fishing Villages" to Carlos Tay and Jesus Francisco Valladares to review. Tay, a resident of Guatemala City, was 26 years old and was my guide and interpreter in Guatemala. He once had a job delivering shrimp and other fish products from the Pacific coast to Guatemala City, and so he was familiar with conditions in the fishing villages. Tay added 4–5 details to the section, but found none of mine incorrect. The Reverend Jesus Francisco Valladares of Choluteca, Honduras, related that it was accurate. At the end of the section, I added material from a newspaper article relating to the fishermen in Quayaquil, Ecuador, an email letter from Javier Rosero relating to life in cockle villages in Ecuador, and a letter received from O. G. Plaza, an official (Microempresarial) with Alcaldia Municipal de Tumaco, Colombia,

regarding the lives of cockle fishermen in southern Colombia.

Topics and Questions Used for the Surveys

Cockle Fishery, Habitats, and Biology

1) Number of harvesters: men, women, children.
2) Number of days/week they harvest.
3) Quantity of cockles harvested per person per day.
4) How much money do harvesters and dealers receive for *A. tuberculosa*, *A. similis,* and *A. grandis*?
5) Widths of cockle zones.
6) How rapidly do cockles grow?
7) Are *A. tuberculosa, A. similis,* and *A. grandis* taken in the same areas?
8) What cockle predators are in the swamps?
9) Have shrimp farms affected cockle harvesting areas?
10) What is the color of the blood of the three cockle species?
11) How often do fishermen harvest in a particular area?
12) What do fishermen do when not harvesting?
13) Are there any government harvesting regulations?
14) When is the peak market demand (ask dealers)?
15) Where are the markets (ask dealers)?
16) How do people prepare cockles for eating?
17) How often do fishermen eat cockles?
18) In what ways do restaurants serve cockles and what do they charge for each?
19) What limits cockle production, supplies or markets?

NOTE TO MYSELF: Measure sizes of cockles from harvests

Villages and Living Conditions

1) What are the fishermen's homes like?
2) What are the sanitary conditions (indoor plumbing, outhouses, etc.)?
3) How is fresh water obtained?
4) How many homes have electricity and what is its source (personal generators, electric lines, etc.)?
5) Do homes have radios or television sets?
6) Where are schools in relation to the villages?
7) What are the costs of school uniforms and other school items?
8) What grades are children in at particular ages?
9) Are all grades taught in the same room?
10) How many years of schooling before a child can read?
11) Is English taught in the schools?
12) Age at marriage?
13) Marriage dissolutions?
14) How many children do women have?
15) Where are babies born?
16) How do children play, and what toys are used?
17) Any birth control methods or abortion?
18) Are children treated for worms?
19) Any medical or dental care? Do people brush their teeth?
20) How long do people live?
21) What assistance do churches provide?
22) Do people use eye glasses or hearing aids?
23) Cost of funerals.
24) Food for livestock (pigs and chickens).
25) Why no vegetable gardens?

Photographic Subjects

1) Fishermen harvesting cockles in natural habitat
2) Boats and bags
3) Fishermen landing cockles
4) Fishermen's hands and faces
5) Buyers purchasing cockles
6) Eating places preparing cockles for serving
7) Processing of cockles
8) Cockles being sold to the public

Government-Industry Cooperative Fisheries Research in the North Pacific under the MSFCMA

WILLIAM A. KARP, CRAIG S. ROSE, JOHN R. GAUVIN, SARAH K. GAICHAS, MARTIN W. DORN, and GARY D. STAUFFER

Introduction

In the United States, the Federal Government is responsible for management of most commercial fish stocks in the Exclusive Economic Zone (EEZ) from 3 to 200 nmi offshore. In most cases, management of these stocks is carried out under provisions of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

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ABSTRACT—The National Marine Fisheries Service's Alaska Fisheries Science Center (AFSC) has a long and successful history of conducting research in cooperation with the fishing industry. Many of the AFSC's annual resource assessment surveys are carried out aboard chartered commercial vessels and the skill and experience of captains and crew are integral to the success of this work. Fishing companies have been contracted to provide vessels and expertise for many different types of research, including testing and evaluation of survey and commercial fishing gear and development of improved methods for estimating commercial catch quantity and composition. AFSC scientists have also participated in a number of industry-initiated research projects including development of selective fishing gears for bycatch reduction and evaluating and improving observer catch composition sampling. In this paper, we describe the legal and regulatory provisions for these types of cooperative work and present examples to illustrate the process and identify the requirements for successful cooperative research.

The MSFCMA was first authorized in 1976, following establishment of the U.S. EEZ. Off the coasts of California, Oregon, Washington, and Alaska, however, NOAA's National Marine Fisheries Service (NMFS) and its predecessor, the Bureau of Commercial Fisheries (BCF) had established a tradition of conducting cooperative research with U.S. fishing companies, and with agencies and organizations from foreign nations long before that date. Following implementation of MSFCMA, policies and regulations for continued cooperative research activities were put in place, and this regulatory framework has evolved during the subsequent 25 years in response to changes in the Act itself and to specific requirements within each of the five regional administrations of NMFS. The last reauthorization of MSFCMA occurred in 1996 (Anonymous, 1996).

The history of cooperative research in the waters off the U.S. west coast and Alaska is long, and it has been remarkably successful and productive. For example, in the Gulf of Alaska, exploratory fishing began in the late 1940's (Ronholt et al.[1]). Bottom trawl surveys were conducted from research and chartered commercial fishing vessels and participants included the BCF, the Fisheries Research Board of Canada, and the International Pacific Halibut Commission. These early research surveys were the precursors of routine, regular (annual, biennial, and triennial) groundfish surveys now carried out by NMFS off the Pacific coast, including Alaska. Most of these surveys are conducted aboard chartered commercial vessels, because the amount of sea time required greatly exceeds the amount of research vessel time available. These surveys are designed and directed by NMFS, the sampling and data collection is conducted by NMFS personnel, and great care is taken to address concerns regarding consistency. Nevertheless, the work is considered to be cooperative and relies heavily on the skill, experience, and participation of skippers and crews for carrying out the fishing operations in support of the scientific objectives of the surveys.

The AFSC resource assessment survey database constitutes the most important and extensive time series available to fisheries scientists in this region. While it may be the most noteworthy product of ongoing cooperation, it is by no means unique. For more than 30 years, NMFS and the fishing industry have cooperated on a broad range of studies in such areas as commercial and research gear development, studies of marine mammals and seabirds, and collection of fish samples for utilization research, age and growth studies, feeding behavior, maturity and reproduction research, and other aspects of fish biology and ecology. In the Gulf of Alaska and the Bering Sea/Aleutian Islands (BSAI) areas, ongoing industry/agency cooperation supports a substantial marine fisheries observer program which is responsible for collecting data essential to stock assessment and inseason management of catch and bycatch. Costs of this program are shared between the agency

[1] Ronholt, L. L., H. H. Shippen, and E. S. Brown. 1978. Demersal fish and shellfish resources of the Gulf of Alaska from Cape Spencer to Unimak Pass 1948–1976 (a historical review) U.S. Dep. Commer. NOAA, Nat. Mar. Fish. Serv., Northwest Alaska Fish. Sci. Cent., Proc. Rep., Aug. 1978, Seattle, 955 p.

and the industry (Karp and McElderry, 1999).

As the Alaska groundfish fisheries have evolved during the last 30 years, so have the technology and information needs of scientists, managers, and participants in the fishery. For example, increased emphasis on bycatch reduction and reduction of marine mammal and seabird takes has stimulated developments in gear technology and fishing methods, while inseason fleet quota monitoring requires accurate real-time catch accounting, and vessel-specific quota monitoring further increases the accuracy and precision requirements for catch accounting. The research needed to address these kinds of questions may be carried out independently by NMFS or participants in the fisheries, but there is often considerable advantage to be gained from a cooperative approach.

In this paper, we review some provisions for cooperative research, describe three cooperative research studies which were designed to evaluate questions pertaining to catch weight estimation, catch composition sampling, and bycatch reduction, and discuss factors which contribute to the success of cooperative research activities.

Provisions for Cooperative Industry/Government Research

Fisheries research conducted within the U.S. EEZ may be authorized either through a Letter of Agreement (LOA), a Scientific Research Permit (SRP), an Exempted Fishing Permit (EFP), or an Exempted Educational Activity Authorization (EEA). LOA's are generally issued to non NMFS research institutions such as state fishery agencies, universities, or foreign government agencies carrying out research in U.S. waters. SRP's are required for all NMFS research activities carried out aboard government-operated or chartered vessels operating under contracts. EFP's are required for industry-sponsored research when suspension of fishing regulations is required (i.e. when fishing would occur in a closed area or during a closed season, or when a prohibited type of gear would be used). EFP's are also required if compensatory fishing is involved. When compensatory fishing is authorized, the vessel(s) involved are allowed to harvest additional fish after the research has been concluded and to sell this fish to help offset research costs. EEA's are required for educational field trips and small-scale sample collecting.

Even though SRP's are not mandated under MSFCMA, NMFS policy requires that they be issued. In addition to describing the planned research and the need for the work, concerns regarding potential impacts of the research on endangered species, marine mammals, and the environment must be addressed in an SRP.

The LOA's, SRP's, and EEA's are issued by NMFS in accordance with agency directives and guidelines. The process for issuing EFP's, however, is more complex. In general, an application which details the reason for the proposed research, the experimental design and procedure, and the required allocations of fish (if any) must be submitted. The application is first reviewed by NMFS (although applications are often developed in cooperation with NMFS). Following satisfactory review by NMFS, the application is reviewed by the appropriate regional Fishery Management Council (FMC). At this stage it may be endorsed, rejected, or sent back to the applicant with recommendations for resubmission. If endorsed by the appropriate FMC, the application is published in the Federal Register to allow opportunities for public comment. Then, providing it meets legal and policy requirements, the permit is issued. Specific permit requirements are detailed in the relevant fishery management plans. Agency participation is not required under an EFP, but industry organizations may work closely with agency scientists when planning and conducting research under an EFP.

An additional vehicle for cooperative research is provided under Public Law 91-412 (U.S. Code 1525) (Anonymous,1970). This statute allows the Secretary of Commerce to engage in joint projects with nonprofit organizations, research organizations, or public organizations or agencies, and apportion the costs equitably. For example, a nonprofit organization, such as a research foundation, could cooperate with NMFS to expand the scope of a resource assessment survey by covering costs associated with provision of an additional chartered vessel. Research conducted under such an arrangement would still require an SRP and would also require a Memorandum of Understanding between the agency and the nongovernmental organization involved. Thus, even though authorization and permitting requirements may depend on whether the work is initiated by the industry or the agency, on the source of funding, or on the objectives of the research itself, it is usually possible to implement a well designed research study which involves industry/agency cooperation in the Gulf of Alaska and the BSAI.

Example 1: Bycatch Reduction

Background

An important aspect of groundfish management in the Gulf of Alaska and Bering Sea Aleutian Islands concerns the so-called prohibited species catch (PSC). In the groundfish management plans for these regions, certain species are considered to be fully utilized by other fisheries and their possession aboard groundfish vessels is restricted or prohibited. For example, trawlers are prohibited from retaining Pacific halibut, *Hippoglossus stenolepis*, and several important Alaska trawl fisheries often close prematurely when their halibut bycatch allowances are reached (Pennoyer, 1997).

Three approaches are available to the industry for reducing halibut bycatch mortality: avoidance of areas where bycatch rates are high, reduction of handling mortality, and modification of fishing methods to reduce bycatch rates. Avoidance measures have been quite successful, and the fleets now take advantage of retrospective data analysis and real-time catch reporting to avoid high halibut bycatch areas. However, target species catch rates are often high in areas of high halibut abundance such that avoidance of these areas will likely reduce a vessel's daily production and therefore income. Reduction of handling mortality is also effective.

Halibut caps are expressed as metric tons of halibut mortality and observers are trained to determine the condition

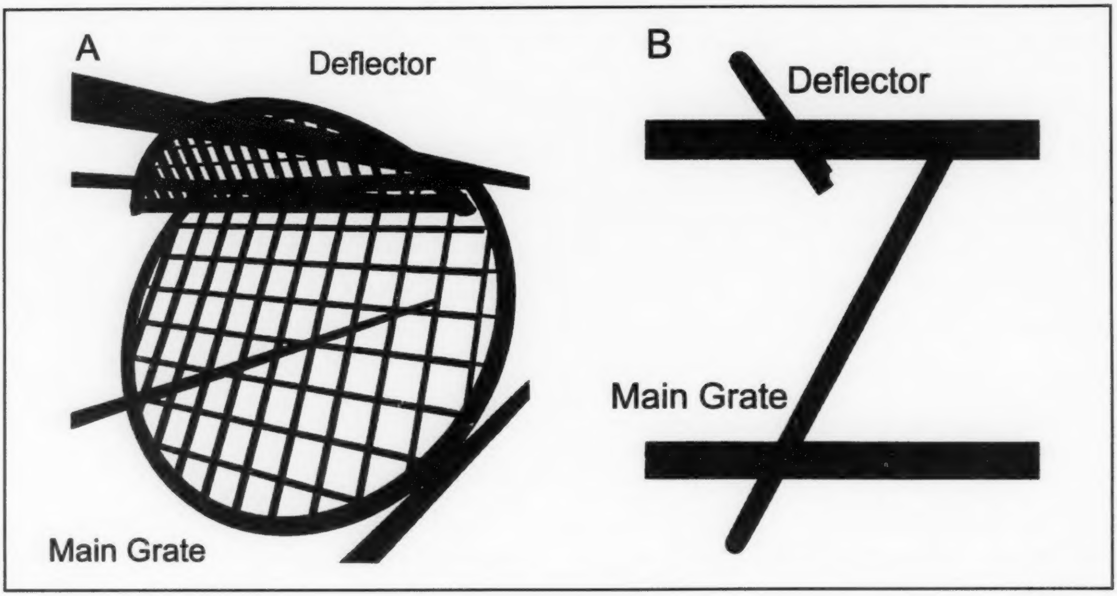

Figure 1.—Oblique view (A) and side view (B) of the halibut excluder grate installed in the intermediate section of a trawl. Mesh sides of the intermediate have not been drawn but riblines are illustrated. From Rose and Gauvin (2000).

(and hence survival rate) of halibut returned to the sea. Survival rates may be enhanced by certain fishing practices, and by taking steps to return incidentally caught halibut to the sea as rapidly as possible. Innovations in gear technology and fishing methodology have also been effective in reducing the retention of intercepted halibut, albeit often at the cost of reduced catch rates for target species. However, owners and operators of some flatfish trawlers have been particularly successful in reducing halibut bycatch rates, and the following section describes research which was initiated to identify one of the more promising innovations and evaluate its effectiveness during a directed flatfish fishery.

Approach

The Groundfish Forum[2], a fishing vessel owners association, submitted an EFP application to test a halibut excluder device for flatfish trawls in April 1998. The EFP was developed with assistance from scientists at the NMFS Alaska Fisheries Science Center and specified the quantities of catch and bycatch species that would need to be caught to carry out the experimental design of the study. The fishing vessel for conducting the EFP was selected through a request for proposals solicitation distributed to owners of interested flatfish trawlers. Individuals submitting proposals were required to describe their proposed bycatch reduction devices and provide necessary supporting information, including fishing practices and resources available to support observers who would be responsible for documenting the quantity and composition of catch and bycatch from each trawl.

[2] Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Summary

The four applications submitted were evaluated by a team of NMFS scientists based on expected effectiveness, history of previous testing, and evaluation of the suitability of the vessel and its fishing gear. A rigid grate design, submitted by the owner of the 36-m (117-foot) F/V *Legacy* was selected.

The halibut excluder consisted of a rigid grate mounted at an angle (bottom further forward than top, approximately 28° slope) in the intermediate section of the net. Fish approaching the grate from the mouth of the net could either pass through the 15 × 15 cm openings into the aft section of the net or be deflected upward toward an escape tunnel. An auxiliary deflector grate was installed with a top-forward slant ahead of the main grate to direct fish downward. It was similar in construction to the main grate but with 7.6 × 7.6 cm openings. The back edge of the deflector and the main grate formed a 23 cm wide slot through which fish had to pass to reach an escape tunnel (Fig. 1).

Since the experimental design required more tows than could be accomplished by a single vessel in the available time, a second vessel was selected, the smaller 33-m (107-foot) F/V *Alliance*. Tests were conducted in 1998 in the Gulf of Alaska on a deepwater flatfish complex including the economically important flatfish rex sole, *Glyptocephalus zachirus;* Dover sole, *Microstomus pacificus;* and flathead sole, *Hippoglossoides elassodon*, and the low-value but abundant arrowtooth flounder, *Atheresthes stomias*.

The experimental design involved paired tows for each vessel. The first tow in each pair or block (control or experi-

mental) was determined randomly, and the second tow was carried out as closely in time and space to the first as possible. Tow duration varied between blocks, and data were analyzed on a catch-per-distance-towed basis. Catch sorting and weighing were carried out by trained, certified observers with assistance from the crew and NMFS scientists.

The combined data sets indicated that, overall, the excluder retained only 6% of the halibut while excluding only 38% of the aggregated deepwater flatfish species. Retention rates for individual flatfish species varied between 48% and 79%. Retention rates were similar for both vessels for all species except rex sole, with a tendency for the larger F/V *Legacy* to allow more escapement than the F/V *Alliance*. Larger halibut were excluded more effectively than smaller individuals, although only fish weighing 3 kg or less were retained in high (46% by weight) proportion. Since length sampling of target flatfish was not a high priority, size-specific retention rates could not be determined.

This research demonstrated the effectiveness of the rigid grate halibut excluder device in reducing halibut bycatch. It was also evident that the device could be handled successfully on a small catcher-processor vessel such as the F/V *Alliance*. Reduction in catches of some target species was, however, of concern and the inability to determine size-specific retention rates of target species is unfortunate.

Further research to evaluate size-specific retention rates and mechanisms for reducing an accumulation of large fish and debris in front of the mesh is warranted, and the investigators suggest that evaluation of mesh excluder systems, which are easier to handle, also be evaluated. Further details can be found in Gauvin and Rose (2001) and Rose and Gauvin (2001).

Example 2: Species Composition Sampling

Background

Sampling for species composition aboard commercial vessels presents unique challenges. Catches may be large and varied, particularly aboard bottom trawlers. Access to the catch may be restricted because of space limitations or processing and operational requirements, and stratification by size and species may occur in the codend. Random or systematic sampling of catch is required for proper characterization of catch composition but may be difficult to achieve.

When fleetwide quota monitoring is the only management goal, within- or among-haul sampling variability may not be of great concern. This is because inaccuracies due to sampling variability generally average out across the fleet and, since all vessels must stop fishing as soon as the overall quota is reached, vessel owners are not greatly concerned about sampling difficulties on their individual vessels. However, when catch or bycatch quotas are managed at the vessel level, managers and owners quickly recognize the potential consequences of biased sampling, and the sampling and estimation process may receive greater scrutiny.

During the last few years, the North Pacific Fishery Management Council (NPFMC) has implemented a number of vessel-specific catch and bycatch programs, and a great deal of attention has been focused on species composition sampling by observers. Sample sizes are often small relative to catch sizes (even a 500 kg sample is small relative to a 30 t or even 150 t catch), and the random sampling requirement may be compromised by vessel operations such that observers only have access to, for example, the first fish to be spilled from the codend after the catch has been dumped. In some of these programs, individual vessels must stop fishing when they reach their catch limit for any of the allocated species, and industry members have raised serious concerns regarding the accuracy of sample-based catch accounting. This may place observers in difficult situations while at sea and has the potential to undermine confidence in the overall catch estimation process.

Thus, both the fishing industry and NMFS identified a need to better understand the problems associated with catch composition sampling in certain fisheries and then to seek solutions to some of these problems. Consequently, the Groundfish Forum took the initiative to draft an EFP application which sought improvements in species composition sampling through identification and quantification of potential inaccuracies of existing sampling practices. The concept and experimental design were developed with the assistance of NMFS scientists.

Approach

The study was designed to examine species composition sampling aboard a trawler targeting flathead sole in the Bering Sea and catching mixed flatfish and roundfish. Interested fishing companies were asked to prepare proposals explaining how catch processing could be managed on their vessels to meet the sampling, catch census, and discard weighing requirements of the study. The factory trawler *American No. 1* was selected. NPFMC and NMFS approved the EFP application which provided for a sufficient quantity of catch and bycatch (672 t in total) to support the sample size requirement for 62 hauls.

From each haul, six 100 kg samples were taken at random for estimation of species composition, then all remaining halibut, snow crabs, *Chionoecetes* spp., and skates, *Rajidae*, were removed and weighed. Production and discard records were also maintained.

Following the fieldwork, the data were analyzed to compare sample-estimated weights to census-based weights for skates, Pacific halibut, and snow crabs (crab comparisons were based on numbers of individuals), and to compare haul-specific, daily, and total-cruise estimates based on observer samples with those based on production and discard estimates for retained species (walleye pollock, *Theragra chalcogramma*; Pacific cod, *Gadus macrocephalus*; yellowfin sole, *Limanda aspera*; Alaska plaice, *Pleuronectes quadrituberculatus*; and flathead sole). Data from individual samples within hauls were also analyzed on a species-by-species basis to determine if stratification (sorting by species and/or size) occurred.

Summary

Even though each method has serious shortcomings, species composition estimates based on observer sampling were

generally similar to estimates based on vessel production plus discards at the haul and cruise level. For commonly occurring species (each making up 15–20% of the composition of individual catches), catch estimates agreed well and variances were low, even at the haul level. However, for bycatch species (generally making up less than 2% of the composition of individual hauls), variances associated with catch estimates were high, particularly at the haul level although agreement between estimates improved when catches were aggregated to the week or cruise level. Within-catch stratification was observed for walleye pollock, yellowfin sole, Pacific cod, Alaska plaice, and "others." Stratification was relatively strong for pollock, yellowfin sole, and Pacific cod and could account for up to 20% of pollock catch estimation variability. Stratification was not detected for crabs. Catches of skate and Pacific halibut were too small to analyze for stratification trends. Sampling conditions during this research cruise were ideal; access to the catches was unrestricted so that observers were able to collect replicate random samples without difficulty. This type of situation rarely occurs during normal fishery operations.

Even though stratification within catches is of concern, this study supports the perspective that current sampling methods are appropriate for fleetwide monitoring of most catch and bycatch quotas. Variability may be high, however, particularly for nontarget species. Stratification may contribute substantially to this variability although its effects may be ameliorated by drawing several random samples from each haul. Observer sampling and production plus discard methods generally produce comparable results.

Concerns arise for the flathead sole fishery and other fisheries with similar catch characteristics, when monitoring for rare bycatch species is on an individual haul or daily basis. Over- or underestimates of rare species can be expected for individual hauls. Thus, the haul-by-haul catch monitoring requirements of individual vessel quota managed fisheries may be difficult to achieve. Many of the vessels participating in the Community Development Quota program in the Bering Sea operate under a requirement that accounting against individual quotas be based on samples taken by observers from each haul. Uncertainty in the resulting haul-by-haul catch estimates may result in premature closures for some vessels and delayed closures for others.

As a result of this study, sampling limitations are better understood by NMFS and the fishing industry. This shared perspective may lead to cooperative solutions to some problems, such as modifications to vessel operations and observer practices to mitigate the effects of codend stratification. It may also result in initiatives to redesign management programs based on unrealistic sampling expectations and, perhaps, to more realistic standards for the design of new programs.

Example 3: Estimation of Catch Weight

Background

In the large-scale catcher-processor trawl fisheries of the BSAI, observers generally estimate catch weight by first determining the volume of the catch and then applying a density factor (volume to weight conversion factor) to calculate weight. In some cases, marked and illuminated holding bins are used to contain individual catches, and volume measurement is relatively straightforward. In most situations, however, suitable bins are not available and observers must resort to making measurements of the codend, using these measurements to estimate catch volume, and then making the conversion to weight using a density factor.

Until recently, managers were concerned only with fleetwide catch estimates so that vessel-to-vessel variability in catch accounting was not taken into account. However, with the advent of vessel-specific management requirements, the need to address vessel specific catch accounting accuracy issues became apparent. Several alternatives for improving catch weight determination are available including direct weighing at sea and improved, standardized methodologies for estimating catch volume coupled with improved density factors.

NMFS recognized the need to evaluate current methods and new approaches but understood that the success of this type of evaluation would depend on the applicability of their findings in commercial fishing situations. Since the results of this research might be used to support potentially unpopular regulatory change, the independence and objectivity of the study was of paramount importance.

Approach

Even though industry participation and cooperation were essential to the success of this research, the study was initiated and designed by NMFS, and the experimental design required NMFS to direct the fishing and processing of the vessel. The participating company would be required to equip its vessel with a motion-compensated flow scale, ultrasonic sensors for measuring depth of fish in bins, and to perform other modifications. They would also be required to conduct research tows within and outside the normal fishing seasons. NMFS issued a request for proposals (RFP) to fishing companies interested in providing a factory trawler with the crew and equipment required to perform the work. Companies responding to the RFP had to address all the requirements laid out in the Statement of Work and provide a bid price, the amount they were willing to pay the government. After the contract was awarded, NMFS issued an SRP which authorized fishing outside the normal fishing season, consistent with the research plan. In this instance, the vessel was allowed to retain catches taken during the research study.

Fieldwork was carried out in 1996 and 1997, although only the 1997 work is summarized here (Dorn et al.,1999). The objectives of this research were to determine the accuracy of a flow scale and evaluate procedures for monitoring flow scale performance, evaluate the accuracy of volumetric methods of catch weight determination, evaluate the use of ultrasonic bin sensors for determining fish volume in holding bins, obtain accurate density factors for use in volume to weight conversion for

walleye pollock catches, and evaluate current and alternative methods used by observers to determine density.

The overall study design required between 150 and 200 individual trawls to be taken over a range of catch sizes. This provided the basis for conducting comparisons of catch weight estimates obtained from the flow scale with volumetric estimates obtained from codend measurements, direct measurements of bin volume, or ultrasonic (bin sensor) measurements of bin volume.

Scale performance was closely monitored during the study. Evaluation of observer methods for estimation of fish density was conducted by estimating density directly (weighing known volumes of fish on the flow scale) and a new method for density estimation by observers was tested. This utilized a prototype sampler designed to address problems with standard observer density estimation methods which utilize small perforated baskets. The prototype was constructed from a plastic barrel of approximately 55 gallons (0.21 m^3) and was designed for ease of filling, emptying, and volume measurement by observers.

Summary

The flow scale was found to be a reliable tool for measuring catch weights and it operated within established error limits throughout the project. However, comparisons with fish samples of known weight indicated a consistent positive bias of approximately 1% during this experiment (Dorn et al., 1999).

Codend volume measurements were found to be consistent and reliable although a tendency for overestimation of volume (or reduction of density) for large codends was apparent when codend volume/density based weight estimates were compared with flowscale observations. Bin volume measurements (for this ideal situation where bins were properly calibrated, marked, and illuminated) were found to be very precise. Ultrasonic bin sensor methods were also found to be reliable except when bins were relatively full.

Results obtained with the density sampler were encouraging. They were consistent and did not vary by observer. Overall, density estimates obtained by the basket and density sampler methods compared well with estimates obtained from flowscale/bin volume methods while flowscale/codend volume estimates tended to indicate higher density values. Based on these results, the investigators recommended changes (increases) in the standard density factors for pollock. They also recommended changes in observer training to improve volumetric estimates of large codends (Dorn et al., 1999).

Discussion and Overall Summary

While each of these studies reviewed here was designed to address a specific area of concern, they share several of the attributes of successful cooperative research. NMFS and the fishing industry have broadly overlapping interests in reducing bycatch, understanding better the constraints on accurate catch accounting, and implementing improvements in catch accounting systems. Furthermore, agency and industry catch accounting concerns have become more acute with the implementation of management programs which require monitoring of individual vessel performance. Thus, NMFS and the fishing industry recognized the need for each of these studies. Industry took the initiative in the first two cases, and took advantage of EFP provisions and the opportunity to work in partnership with NMFS. In the third case, NMFS identified the need to carry out the work, and determined that contracting with a fishing company would be necessary. As in all situations where the agency initiates the research, an SRP was required for this study.

When the Groundfish Forum initiated the bycatch study they recognized the advantages of working with NMFS scientists knowledgeable in the field of experimental design and fish behavior in relation to fishing gear. The concept of evaluating potential participants on the basis of the design of their bycatch reduction device was particularly innovative and would have been difficult to implement in a NMFS-initiated study. The Groundfish Forum's ability to act quickly to implement the work following approval of the EFP illustrates an additional benefit of the industry-initiated approach.

The catch composition sampling study was also initiated by the Groundfish Forum. NMFS scientists had been working on improved sampling protocols, enhanced observer training, and industry outreach to address sampling accuracy concerns, and they recognized the opportunities afforded by the Groundfish Forum research proposal. The Groundfish Forum was able to develop its proposal in response to industry concerns regarding the potential problems associated with sampling biases when catch accounting occurs on a haul or vessel-specific basis. And, again, they were able to implement the study much more rapidly than would have been the case in a government-initiated study.

NMFS initiated the catch-weight estimation study. Evaluation of flowscale performance at sea was essential given the direction of the NPFMC to require these systems aboard certain vessels. NMFS took advantage of this opportunity to evaluate current and innovative volumetric methods and an improved method for density estimation at sea. It was essential that the work be carried out aboard a commercial vessel during normal, production fishery operations. The direct participation of fishing company personnel contributed markedly to the success of the work and to the credibility of the results. However, the contractual arrangement did provide government scientists with the authority to direct scientific operations and to make changes in the research plan when minor problems arose. As a consequence of this study, NMFS adopted a revised standard density factor for converting pollock catch volume estimates to estimates of weight. Because the new density factor was higher than the one previously employed, this result was not popular with the fishing industry. Therefore the results received a high degree of scrutiny. The results of cooperative research cannot always be expected to be welcomed by all parties involved.

Integral to each of these studies were the certified observers of the NMFS North Pacific Groundfish Observer Program. Observers are deployed aboard groundfish vessels to document catch

quantity and composition; their training and experience makes them uniquely qualified to collect research data in studies of the type described herein. Furthermore, each of these studies was concerned, to some degree, with observer sampling methodology, and the catch weight and catch composition sampling studies provide significant opportunities for evaluating and improving observer data collection protocols. The catch sampling requirements for studies of this type are often extremely demanding, and the availability of suitably trained and experienced field biologists is of paramount importance. Because of the involvement of observers in these studies and, especially, because observer sampling practices were evaluated explicitly during two of the projects, opportunities were afforded for industry to recognize the difficulties that observers encounter when performing sampling duties aboard fishing vessels. This has resulted in some suggestions for innovative solutions to sampling problems and improved recognition of the limitations of the observer-based catch monitoring system.

The success of cooperative studies depends on the ability of scientists and industry personnel to work together at all levels, including the senior staff who develop research concepts and provide political and fiscal support, those involved in the detailed design and planning, and scientists and industry personnel involved in data collection, analysis, and reporting. This commitment may be seriously tested when research results are not deemed favorable. The finding that led to an increase in the standard density factors for estimating pollock catch weight was unpopular with the industry, so questions regarding the applicability of the study had to be resolved. As a result of the catch composition sampling study, agency assumptions regarding the appropriateness of basing haul and vessel-specific catch accounting on sample data collected by observers have been challenged.

Collaborations between NMFS and industry may be particularly attractive, because NMFS allows retention and sale of fish caught during the EFP to fund the research that would otherwise be too costly to conduct. For instance, the EFP research to investigate catch composition sampling in the multispecies flatfish fishery provided a set aside of flatfish and other species for the fishing associated with the experiment. The company owning the vessel that participated in the sampling experiment was able to support the vessel's fishing costs and the substantial additional crew duties associated with the experiment from the proceeds of the sale of fish caught during the experiment. The expected charter cost of the vessel to conduct the experiment without retention of the catch would have been approximately \$20,000 to \$25,000 per day or close to \$500,000 over the 3 weeks of the experiment. This estimate is based on the vessel's expected revenue per day if the vessel participated in one of the possible fisheries open at the time of the experiment.

For certain types of research, the applicability of the results may depend upon the extent to which research conditions resemble the actual commercial fishing conditions. This resemblance is likely to be greater when the vessel depends on the revenues from the fish it catches. For instance, if the sampling research had been conducted under a research charter, the skipper and crew would, perhaps, have had an incentive to catch smaller quantities with less complex composition than would occur in a normal commercial catch. This is because the extra work of sorting and weighing catch by species would be less if the catch per haul was smaller or less diverse.

We have described only three of the many successful cooperative studies that have taken place in the waters off Alaska. We have also demonstrated that either industry initiated or agency initiated cooperation can be effective. In some cases, such as the long-term charters for annual stock assessment surveys, agency initiated contractual arrangements are the most suitable. In other cases, such as the bycatch study discussed above, industry initiated research is more appropriate. For other cases, either approach could be successful. Regulatory provisions developed under the MSFCMA and other statutes, together with agency administrative procedures, provide viable mechanisms for supporting cooperative research. Of paramount importance, however, is the commitment by agency and industry personnel to work together and to recognize the importance of carrying out high quality, scientifically defensible research, regardless of the results which might be obtained.

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The Demand for Eastern Oysters, *Crassostrea virginica*, from the Gulf of Mexico in the Presence of *Vibrio vulnificus*

WALTER R. KEITHLY, Jr., and HAMADY DIOP

Introduction

The bacteria *Vibrio vulnificus* is a naturally occurring organism in estuarine waters and is found in an unknown proportion of eastern oysters, *Crassostrea virginica*, harvested from the Gulf of Mexico (hereafter, the Gulf). The presence of *Vibrio vulnificus* is highly correlated with water temperature, and virtually all Gulf-harvested oysters contain some concentration of it in the warmer summer months (McQuaid, 1997). As noted by Corcoran (1998) in the Nutrition Action Healthletter: "[e]very year, more than 50 people become ill and at least 10 die after eating uncooked Gulf Coast oysters that are contaminated with *Vibrio vulnificus* bacteria." Most of these illnesses and deaths occur between May and October.

California, in response to this health concern, initiated a program on 1 March 1991 which required anyone selling Gulf oysters to notify potential consumers that the "consumption of raw oysters can cause illness and death among people with liver disease, chronic illnesses, or weakened immune systems" (Liddle, 1991). California's mandatory warning received extensive coverage in newspapers (and the trade literature) both there and across the country and particularly in the Gulf region.[1]

In a further step to promote public safety, the U.S. Food and Drug Administration (FDA) in 1994 proposed banning consumption of raw oysters from the Gulf from April through October when *Vibrio vulnificus* was most prevalent. After "heavy pressure from the Gulf oyster industry and members of Congress from Louisiana and other Gulf states," the FDA backed away from its initial proposal and instead opted for a "public awareness campaign" to notify and educate those people at risk (McQuaid, 1997).

The primary goal of this paper is to examine the extent to which the demand for Gulf oysters has been reduced as a result of the mandatory warning labels and associated media attention and to examine the impact on consumer welfare associated with further regulation of the harvesting sector. A secondary goal of the paper is to analyze the impacts of other factors, such as the quantity harvested and income, on the demand for Gulf oysters. To accomplish these goals, an overview of the oyster industry is presented here, followed by a review of relevant literature. Then, the model used for the analysis is specified, and the data and estimation issues are briefly examined. The empirical results are then presented, and the paper concludes with a discussion of the implications of the findings.

Industry Overview

The U.S. oyster industry operates on both the U.S. east and west coasts. The primary oyster species harvested on the east coast (i.e. Atlantic and Gulf), the eastern oyster, produced average annual landings of about 31 million pounds during 1981–97 with an associated \$77 million dockside value (NMFS[2]). Annual landings of Pacific oysters, *Crassostrea gigas*, the primary west coast species, averaged about 9 million pounds valued at \$18 million (dockside) during 1981–97.

Gulf oyster production averaged 20 million pounds annually during 1981–97, or about 60% of the total eastern oyster production. Louisiana, the primary producer there, accounted for almost 60% of the Gulf output, while Texas accounted for an additional 20%.

Chesapeake Bay, once the nation's largest oyster source, has seen production fall sharply since the early 1980's

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ABSTRACT—California, in response to health concerns, initiated a program on 1 March 1991 which required anyone selling eastern oysters, Crassostrea virginica, *from the Gulf of Mexico area to notify potential consumers that there was a risk in consuming them raw. This mandatory warning, followed shortly thereafter by a similar warning in other states, including Louisiana and Florida, received extensive press coverage throughout the country and particularly in the Gulf area. This paper examines the extent to which the demand for Gulf-area oysters has been reduced as a result of mandatory warning labels and negative publicity. In general, the results suggest that since 1991 the "summer" dockside price has been reduced by about 50% as a result of warning labels and associated negative publicity, while the "winter" dockside price has been reduced by about 30%.*

[1] Subsequently, other states—most notably Louisiana and Florida—have enacted mandatory warning label programs similar to that of California.

[2] NMFS Commercial Fisheries Landings data compiled by the Fisheries Statistics and Economics Division, Office of Science and Technology available at http://www.st.nmfs.gov/commercial.

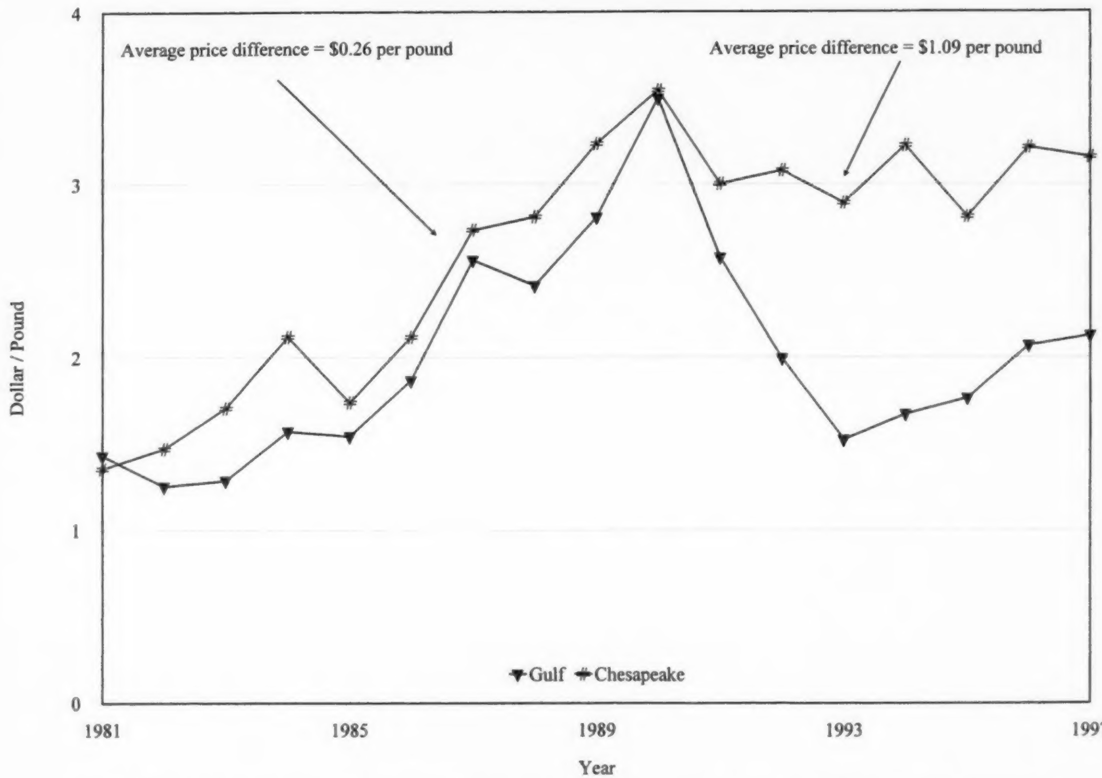

Figure 1.—Annual dockside oyster prices (current) in the Gulf and Chesapeake regions, 1981–97 (NMFS text footnote 2).

due to habitat degradation, overfishing, and disease (Rothschild et al., 1994). Then averaging close to 17 million pounds annually, the Chesapeake's output fell more than 90% to about 1.5 million pounds annually during 1995–97 (NMFS[2]).

Prior to 1991, annual dockside Gulf and Chesapeake oyster prices tended to "mirror" one another, with annual price differentials rarely exceeding $0.40 per pound (NMFS[2]) and an average price differential equal to only $0.26 per pound (Fig. 1). Since 1991, however, the prices in those regions have become decidedly more distinct, with the average annual price differential exceeding $1.00 per pound. The large price differential since 1991 provides some preliminary evidence that the mandatory warning labels and media attention may have impacted demand and, hence, price of the Gulf product.

Theoretical Basis and Literature Review

Strand (1999) reviewed the literature pertaining to consumer behavior with respect to food-borne contamination events, concluding that the information related to an event, which is subjectively evaluated by consumers, is critical to perception formation. He further suggested that uncertainty contained in the information can also be critical in perception formation. Finally, Strand suggested that the credibility of the information depends on its source.

Perceptions, of course, can alter consumer choice. Strand (1999) further concluded that consumers react to negative news by reducing demand for the product and/or by taking defensive actions to lower the level of health risk. Furthermore, as a result of uncertainty (e.g. uncertainty of the marketing channels through which they obtain their consumables), consumers may reduce demand even though there is no scientifically supported risk to them from normal consumption. Finally, Strand (1999) suggested that changes in demand owing to reports of persistent toxic compounds (like DDT) appear to be a reaction to cumulative news reports, and while the effects associated with news will decay over time, the decay is slow.

Strand's synthesis of the literature provides several insights that are relevant to this study. First, one might hypothesize that consumers have reacted to the negative publicity concerning the consumption of raw Gulf oysters by reducing demand for the raw product and/or taking defensive actions to lower the level of health risk. Such actions may include increasing demand for the processed product vis-a-vis the raw product or by reducing consumption only in the

"summer" months when health risks (in terms of mortality) from the consumption of raw oysters are greatest.

Second, uncertainty is likely to be a major factor in determining the change in demand for Gulf oysters. The uncertainty is inherent in both the information presented to the consumer as well as uncertainty presented to the consumer as to whether he/she possesses the health characteristics (i.e. liver disease, chronic illness, or a weakened immune system) that would make the consumption of raw oysters "risky."

Third, one could argue that the change in demand for Gulf oysters is analogous to Strand's (1999) discussion regarding changes in demand for food products resulting from reports of persistent toxic compounds. Specifically, while *Vibrio vulnificus* is not a toxic compound, like some such compounds, it is persistent in nature and continues to receive adverse publicity several years after the initiation of warning labels.

Model Specification

For purposes of analysis, the demand for Gulf oysters is specified as:

$$\begin{aligned} PG_t = \beta_0 + \beta_1 VUL_t + \\ \beta_2 SEAS_t + \beta_3 QG_t + \\ \beta_4 INC_t + \beta_5 (SEAS*VUL)_t + \\ \beta_6 (QG*SEAS)_t + \\ \beta_7 LATX_t + \beta_8 LPG_t + \epsilon_t \end{aligned} \quad (1)$$

where PG_t denotes the deflated Gulf oyster dockside price in quarter *t*, expressed in dollars per pound of meats (1997 Consumer Price Index equals base); VUL_t is a binary variable used to "capture" the change in demand due to warning labels and associated media attention (equal to 0 before 1991 and 1 thereafter)[3]; $SEAS_t$ is a binary variable used to "capture" seasonality in the demand for Gulf oysters equal to 0 for the months April through September, (i.e. the 2nd and 3rd quarters) and 1 for all other months, (i.e. the 1st and 4th quarters); QG_t denotes the Gulf oyster harvest, expressed in millions of pounds of meats, in quarter *t*; INC_t denotes the U.S. real disposable income in quarter *t*, expressed in billions of dollars; $LATX_t$ denotes the share of Gulf oyster production accounted for by Louisiana and Texas in quarter *t*; LPG_t denotes the deflated Gulf price lagged one quarter; and ϵ_t denotes the error term. Parameters to be estimated range from β_0 to β_8.

The equation, as specified, is price dependent. This reflects the fact that production in the Gulf tends to be determined, to a large degree, by the availability of oysters which, in turn, is largely dictated by environmental influences, particularly in the short run.[4]

The variable VUL_t was included to "capture" any decrease in demand associated with warning labels and media attention while the variable $SEAS_t$ was used to "capture" seasonal variation in demand. Since the incidence of *Vibrio* is temperature dependent and is higher in the warmer months of the year, it is further hypothesized that the impact of VUL_t may vary by season with the impact on demand being greater in the "summer" months. To account for the possible variation in impact by season, an interaction term between $SEAS_t$ and VUL_t is included in equation 1.

It is anticipated that price in quarter *t* responds inversely to changes in Gulf harvest (QG_t) and positively to changes in income (INC_t). Furthermore, given the interaction between harvest and season $(QG*SEAS)_t$, the response in price to a change in the quantity harvested is permitted to vary by season.

Louisiana and Texas, as noted, generally account for the majority of Gulf oyster production. There appears to be a premium attached to the price of oysters harvested from these two states, perhaps due to a larger average size. Hence, one would expect that the average Gulf price is positively related to the share of production derived from these two states. The variable $LATX_t$ is included in equation 1 to "capture" the price effect resulting from product heterogeneity across states.

The variable LPG_t is used to model inertia in the change in dockside price (PG_t) to changes in exogenous variables. The value of β_8 is expected to fall between 0 and 1 with a value approaching 0 indicating instantaneous adjustment in price to changes in the value of exogenous variables, while a value approaching 1 suggests a high degree of inertia.

Finally, substitute products are often entered as exogenous variables in demand models of this nature. One would hypothesize that oysters produced in other regions of the country might constitute substitutes for the Gulf product. Chesapeake oysters, given the similarity in the type of oyster produced and the geographic relation, were considered a potential substitute product, a priori. Initial inclusion of Chesapeake production in the Gulf demand equation did not prove to be successful and, hence

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[3] While many studies which evaluate the impact of information on consumer demand quantify the amount of information available at regular intervals (Swartz and Strand, 1981; Johnson, 1988) or the amount of cumulative information (Brown and Schrader, 1990), the use of such procedures were, for several reasons, impractical with respect to the current study. First, the information is received from both warning labels and the print media, and any attempt to isolate these two factors would be problematic. Second, a large percentage of raw oyster consumption occurs in the away-from-home market, and much of the information appears to occur in trade journals. Hence, one would need to isolate the impact related to information in trade journals from that of the more common news media. Finally, most studies that have evaluated the impact of negative information on demand are based on products for which the duration was of only a limited period of time. With respect to the impact of *Vibrio vulnificus* on the demand for Gulf product, the publicity is of longer or continuing duration.

[4] A reviewer suggested that, because of leasing activities in Louisiana and Texas, quantity harvested may not be exogenous to the system. To examine this issue, a vector autogressive model between Gulf price (PG) and quantity (QG) was estimated as follows:

$$QG_t = \alpha_0 + \alpha_1 QG_{t-1} + \alpha_2 PG_t + \alpha_3 PG_{t-1} + \xi_{1t}$$
$$PG_t = \beta_0 + \beta_1 PG_{t-1} + \beta_2 QG_t + \beta_3 QG_{t-1} + \xi_{2t}$$

where QG_{t-1} represents the Gulf landings lagged one period and PG_{t-1} is the Gulf price lagged one period. The Gulf oyster price is said to be block exogenous with respect to Gulf landings if the elements in Gulf price are of no help in improving the forecast of Gulf landings based only on lagged values of PG. The null hypothesis is "PG is not exogenous to QG" which is equivalent to $\alpha_2 = \alpha_3 = 0$. The test statistic follows a chi square distribution with one degree of freedom. The associated chi square statistic of 0.01 (significance level is 3.84) at the 5% significance level implies that PG is not exogenous to QG. In contrast, the test statistic of 12.56 (significance level is 3.84) implies that QG is exogenous to PG. These results agree with the hypothesis that current Gulf landings contribute significantly to the improvement of the forecasted price based only on lagged prices. However, current and lagged prices do not statistically improve the forecasted landings based only on lagged landing values.

the variable was not included in the final version of the model discussed in the following sections.[5]

Data and Estimation Issues

Data Issues

The Gulf dockside demand model developed in the previous section was estimated with quarterly data for the 1981–97 period. Where appropriate (i.e. prices and income), the data were deflated using the 1997 Consumer Price Index. Some summary statistics for the variables included in the model are presented in Table 1. The deflated Gulf oyster price averaged $2.63 per pound, with the post 1990 price ($2.13 per pound) being nearly 30% less than the pre 1991 price ($2.98 per pound). The quantity harvested averaged 5.2 million pounds per quarter during the period of analysis, with the pre 1991 quarterly production (5.4 million pounds) averaging about 8% more than the post 1990 quarterly production (4.9 million pounds).[6]

In general, little price variation was evident during the 1981–97 period when examined on a seasonal basis, even though production during the "winter" season, which averaged 6.1 million pounds per quarter, exceeded the production during the "summer" season, which averaged 4.28 million pounds per quarter, by about 40%. Since 1991, "winter" season production has averaged 5.7 million pounds per quarter compared to 4.2 million pounds per quarter in the "summer" season.

Estimation Issues

The lagged dockside price (LPG_t), as noted, was included in the analysis, based on the premise that the response in price to a change in an exogenous variable may not be completed in that quarter in which the change in the exogenous variable occurred (i.e. there exists some inertia in the change in price). Assuming a geometric lag structure, this inertia, can be expressed as :

$$Y_t = \alpha + \beta\,(X_t + wX_{t-1} + w^2X_{t-2} + ...) + \epsilon_t \qquad (2)$$

where w is the lagged weight ($0<w<1$) which declines at a geometric rate over time. As specified, equation 2 is difficult to estimate due to the infinite series of lagged regressors.

As shown by Madalla (1977) and Pindyck and Rubinfeld (1991), equation 2 can be rewritten as:

$$Y_t = \alpha(1-w) + wY_{t-1} + \beta X_t + (\epsilon_t - w\,\epsilon_{t-1}) \qquad (3)$$

Expressed in this manner, the geometric lag model can be easily estimated, given the finite series of the lagged variable (i.e. Y_{t-1}) .

The implications associated with equation 3 are twofold. First, all past values of the exogenous variable (X_t) are captured in the endogenous variable (Y_t) lagged one period with impact of a change in X_t on Y_t decaying at a geometric rate over time. Second, lagging the dependent variable results in the introduction of serial correlation of the error term, assuming ϵ_t in equation 2 does not exhibit an autocorrelation pattern.

Several methods have been proposed for estimating the geometric lag structured model in the presence of serial correlation. The most popular technique, and the one that is used in the current analysis, is the instrumental variable approach whereby an estimate of the lagged dependent variable is generated by regressing its value against the lagged values of the exogenous variables in the model. Then, the model is estimated using a maximum likelihood procedure.

Given the structure of a geometric lag model, it is useful to identify the long-run impact associated with a permanent change in the level of an exogenous variable. Madalla (1977) shows that this impact is equal to $\beta/(1-w)$. Hence, as the value for w increases ($0 < w < 1$), the greater will be the amount of time which expires before the full impact of a one-time change in an exogenous variable is recognized. This, in turn, implies that the difference between the immediate impact (β) and long-run impact ($\beta/(1-w)$) increases in relation to an increasing value of the lagged weight (w).

Empirical Results

Table 2 summaries the regression results associated with the Gulf dockside demand model. The estimated parameters, in general, agreed with prior expectations and, with few exceptions, all estimated parameters were significant at the 90% confidence level. Furthermore, the estimated model explained almost 90% of the variation in the deflated Gulf dockside price (Table 2, Fig. 2).

Overall, increased information related to *Vibrio vulnificus* was found to significantly influence the demand (price) for Gulf oysters. Specifically,

Table 1.—Summary statistics pertaining to the Gulf of Mexico oyster demand model.

Variable	Overall mean[1]	"Winter" mean	"Summer" mean
1981–97			
PG ($/lb)	2.63 (0.81)	2.59 (0.83)	2.66 (0.80)
QG (Mill lbs)	5.20 (1.91)	6.11 (2.08)	4.28 (1.17)
INC ($ bill)	4,905.7 (588.0)	4,908.6 (593.3)	4,902.8 (591.6)
LATX (%)	0.77 (0.10)	0.74 (0.09)	0.79 (0.10)
1981–90			
PG ($/lb)	2.98 (0.82)	2.93 (0.87)	3.02 (0.79)
QG (Mill lbs)	5.38 (2.20)	6.40 (2.48)	4.36 (1.27)
INC ($ bill)	4,524.3 (442.2)	4,527.1 (447.8)	4,521.4 (448.1)
LATX (%)	0.76 (0.11)	0.73 (0.12)	0.78 (0.11)
1991–97			
PG ($/lb)	2.13 (0.46)	2.11 (0.44)	2.15 (0.49)
QG (Mill lbs)	4.94 (1.40)	5.71 (1.31)	4.16 (1.05)
INC ($ bill)	5,450.5 (228.6)	5,453.5 (238.3)	5,447.5 (227.5)
LATX (%)	0.78 (0.08)	0.75 (0.05)	0.81 (0.10)

[1] Standard errors of means are given in parentheses.

[5] For comparison purposes, the model that includes Chesapeake production as an explanatory variable is included in the table that provides empirical results (Table 2).

[6] Much of the difference in pre and post 1990 production can be attributed to abnormally low production in Louisiana in 1991 and 1992. Low production in those years reflects massive oyster mortalities from excessive rainfall and, hence, lower salinity.

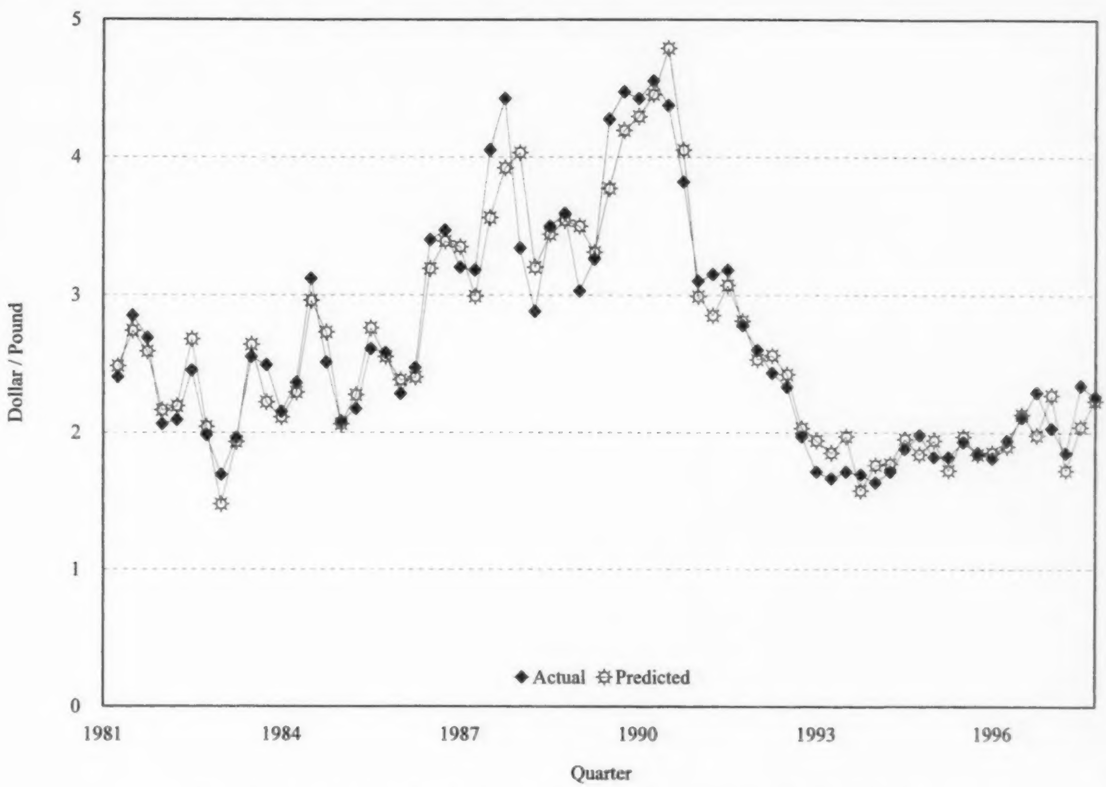

Figure 2.—Actual and predicted quarterly dockside Gulf oyster price (deflated), 1981–97.

the warning labels and associated media attention (VUL_t) resulted in an immediate reduction in the "summer" dockside price by $0.93 per pound compared to a reduction in the "winter" price of $0.72 per pound. These reductions, however, reflect only the initial impact. The fact that the estimate of β_8, equal to 0.553, falls between 0 and 1 implies that as one moves further away from the date that warning labels were initially mandated, the greater the absolute value of the magnitude of the policy variable.

Table 2.—Estimated parameters and standard errors associated with the Gulf of Mexico oyster demand model.

Variable	Estimated[1, 2] parameter	Standard error	Estimated[1, 3] parameter	Standard error
Intercept	0.669	0.537	0.349	0.606
VUL_t	–0.929*	0.174	–0.955*	0.175
$SEAS_t$	–0.624*	0.203	–0.741*	0.227
QG_t	–0.217*	0.036	–0.217*	0.036
QC_t			0.027	0.024
INC_t	0.372E-3*	0.134E-3	0.427E-3*	0.142E-3
$(SEAS \cdot VUL)_t$	0.213**	0.114	0.299*	0.137
$(QG \cdot SEAS)_t$	0.109*	0.036	0.111*	0.036
$LATX_t$	0.165	0.416	0.209	0.417
LPG_t	0.553*	0.076	0.557*	0.076

[1] * = statistically significant at the $\alpha = 0.05$ level; ** = statistically significant at the $\alpha = 0.10$ level.
[2] Model estimated without Chesapeake landings (QC_t) as an exogenous variable; adj. R^2=0.88.
[3] Model estimated with Chesapeake landings (QC_t) as an exogenous variable; adj. R^2 = 0.88.

In the long-run, the impact of warning labels was estimated to result in a decline in the "summer" dockside price equal to $2.07 per pound and a "winter" reduction in price equal to $1.60 per pound. The actual "summer" price in 1997 equaled $2.16 while the actual winter price equaled $2.22, suggesting that the "summer" price has been reduced nearly 50% as a result of the warning labels and negative publicity, while the "winter" price has been reduced by about 30%.[7]

[7] One could hypothesize that the impact of warning labels and the associated negative publicity (continued) decays at some rate with the passage of time as consumers either forget about the negative publicity or overcome initial fears. To examine whether this was the case, the analysis was also conducted for the 1981–93 period. In general, the parameter estimates varied only marginally (e.g. $\beta_1 = -0.929$ and $\beta_5 = 0.265$), suggesting that the decay in the initial impact is, at most, minor.

With respect to the Gulf landings (QG_t), the results suggest that a 1,000,000 pound increase (decrease) in "summer" harvest results in an immediate $0.22 decrease (increase) in price. An equivalent change in the "winter" harvest, by comparison, results in an immediate inverse price response of only $0.11 per pound, or about half of that estimated for the "summer" season. In the long-run, a 1,000,000 pound increase (decrease) in "summer" harvest was found to result in a $0.48 decrease (increase) in the Gulf dockside price, while a 1,000,000 pound increase (decrease) in the "winter" harvest was estimated to result in a price decrease (increase) of $0.24 per pound.

With respect to seasonality, the results suggest that the demand for Gulf oysters in the "winter" season exceeds demand in the "summer" season, with the expected price differential equaling about $0.07 per pound ceteris paribus, prior to 1991.[8] After 1991, in association with the warning labels and media attention, the difference in demand between the "winter" and "summer" seasons resulted in an expected price differential of $0.21 per pound.

Income, as indicated in Table 2, was found to significantly influence the Gulf oyster dockside demand. Overall, the results suggest that a $100 billion dollar increase in real disposable income would result in an immediate $0.04 increase in price and a price increase equal to $0.08 increase in the long run.

Discussion and Conclusion

A model was developed and analyzed to examine the impact of mandatory warning labels and the associated negative publicity on dockside price of Gulf oysters. Results suggest that the impact has been significant. Specifically, the results suggest that the "summer" price has been reduced by about 50% as a result of the warning labels and associated negative publicity, while the "winter" price has been reduced by about 30%.

The results developed in this paper can be used to assess the impacts of various policy measures. For example, the FDA, as noted in the introduction, proposed a restriction on sales of raw oysters for consumption from April to October when the *Vibrio vulnificus* bacteria is most prevalent in Gulf waters. From a welfare economics perspective, such a ban would lead to a net increase in the welfare of society if the benefits of taking action (i.e. prohibiting raw oyster consumption) exceed the costs. Benefits reflect, primarily, the reduction in premature deaths and illnesses. Costs, on the other hand, reflect the reduction in consumer and producer welfare (i.e. surplus) which would be incurred as a result of the ban.

As noted by Corcoran (1998), at least 10 people die annually from the consumption of raw Gulf oysters, while more than 50 become ill (an average of 17 individuals died annually during 1996–98). While assigning an economic value to a statistical life is problematic (Kuchler and Golan, 1999), recent empirical work, based on labor market analysis, suggests that the value of a statistical life, expressed in 1997 dollars, falls in the neighborhood of about $4–8 million (Viscusi, 1993, and Moore and Viscusi, 1988 provide details).[9] This suggests that the benefits from the proposed ban, excluding the reduction in illnesses, would approximate $40– 80 million annually.

An "upper bound" estimate of the loss in consumer welfare associated with such a ban can be generated under the assumption that production is equal to zero in those months that would be impacted by the proposed ban.[10] Based upon 1997 quarterly data and estimates, an "upper bound" estimate of the loss in consumer surplus in 1997 from the proposed ban would have been about $6,500,000 based on the 1997 dockside value of $21,200,000 (April through October).

While cost information on the Gulf oyster harvesting sector is insufficient to accurately estimate the loss in producer welfare associated with the proposed ban, it is obviously just a small fraction of the $21,200,000 in revenues generated during the April through October 1997 period. This fraction and the $6,500,000 loss in consumer welfare is considerably less than the $40–80 million annual benefits that would be forthcoming as a result of the ban. Hence, one could conclude that the welfare of society would be enhanced if the eating of raw Gulf oysters were seasonally restricted.

The FDA, as previously indicated, chose not to institute a ban on the consumption of raw Gulf oysters in the "summer" season, opting instead for a "public awareness campaign" to notify and educate those consumers at risk. As noted by Henson and Caswell (1999: 591), policy interventions by governments reflect an "...outcome of a complex trade-off between alternative demands that reflect the interests of the different groups that might be affected. In the case of food policy this will include consumers, food manufacturers, food retailers, and farmers, both at home and abroad, as well as government itself and taxpayers." Whether the alternative strategy (i.e. the awareness and education program), derived via this complex trade-off between alternative demands, proves to be as successful as a seasonal restriction would be has yet to be determined.

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[8] As indicated in Table 1, the observed 'summer" price exceeded the "winter" price by $0.05 per pound prior to 1991. Given the results of the current analysis, it appears as though the higher observed "summer" price reflects a lower level of production.

[9] The value of a life refers to the amount of money an individual is willing to trade for a small change in his or her probability of survival (Blomquist, 2001)

[10] Only an "upper bound" estimate of the loss in consumer welfare can be derived, because an unknown percentage of the "summer" season harvest is currently processed, which is not subject to the proposed ban. Furthermore, if the ban were to be implemented, the demand for processed product would likely increase resulting in a greater proportion of the harvested "summer" product being directed towards the processing sector.

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